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Growing environmental awareness and repeated reports on the potential negative effects of electromagnetic fields, commonly known as electrosmog, on the human organism are increasingly giving rise to public debate on this subject.

GUIDELINES
Even though scientific proof of the harmfulness or indeed harmlessness of electrosmog has yet to be established, the desire for precautionary measures means that the call for political and legal regulations has continued unabated. The determination of exposure limits was set in motion at the beginning of the 90's: The IRPA (International Radiation Protection Association) has issued new guidelines, Germany has promulgated a law on exposure levels for the general public, Switzerland has announced a regulation governing field concentrations in the workplace, Australia is working on a new standard and revised limit values, and in the USA this year, the new FCC Standard for the telecommunications branch was brought into force.

MEASURING TECHNOLOGY
Such guidelines bring about the need to monitor workplaces or areas of exposure accessible to the public for compliance with the applicable standards; members of the public who spend time in these areas must be protected and warned if necessary. The challenge facing the measuring technology required for this task is, above all, to provide users with simple, reliable and practical systems. After all, people's safety - and therefore your safety - is at stake.

INNOVATIONS
Wandel & Goltermann are facing this challenge and designing user-friendly “technology for the protection of health”. Here, as always, you can count on decisively innovative steps: Radiation meters with 60 dB dynamic range, personal monitors capable of simultaneously measuring electric and magnetic fields, analyzers with selective frequency display, long calibration intervals of at least two years, and three-dimensional measurement of low-frequency electric fields.

IN PRACTICE
This report is a response to the frequent questions asked by our customers regarding the use of these instruments in practice and international experience. The background is world-wide endeavour in standardizing regulations on limit values and harmonizing measurement procedures.

REPORTS
In the extracts of reports that follow, users of Wandel & Goltermann systems speak out on the basis of their personal specialist knowledge, organizational background and national environment.

CURIOUS?
You may rightly be eager to find out what is in the following reports of people's experiences. It only remains for me to thank all those involved. I am convinced that we are thereby contributing to the recognition of “electrosmog” as a valid object of scientific study. The first step is the reproducible measurement of fields. A possible second step would be your own personal experiences - surely a valuable contribution to this international exchange of information. The editors would therefore be glad to hear from you by post, fax or email.
The experts at the Centre for Electromagnetic Safety periodically conduct measurements of the strength of power supply frequency (50 Hz) electric and magnetic fields in living quarters located in the immediate proximity of power distribution system units, such as transformer substations, switchboards, etc. We successfully use the EFA-3 electromagnetic field analyzer with precision H-field sensor (A = 100 cm²).

Unfortunately, in Russia there are currently no national standards regulating limit values for electromagnetic radiation levels in a given situation. Therefore, we are usually guided by the limit values which are specified in the Swedish MPR-II standard, and by the recommendations of the Swedish Radiation Protection Institute and National Board of Occupational Safety and Health. We accept an electric field strength limit value of 25 V/m and a magnetic flux density limit value of 200 µT.

The measurement method we use is quite simple and, in our view, effective. The surface of the room to be measured is divided into square elemental cells so that a grid pattern is formed, and measurements are taken at the nodes. As the electromagnetic field structure is inhomogeneous, the measurements at each point are made at heights of 0.5, 1.0 and 1.7 m above floor level. The highest of the three values is considered as the defining value.

Results stored in the internal memory of the EFA-3 are transmitted to a PC using the Transfer Set via an optical interface. Here, data recording and consequent processing are carried out with the help of programs such as Microsoft® Excel™.
The results of the processed data are represented in Figures 1 and 2. Safe areas, where electromagnetic field levels do not exceed the limit values, are marked in white.

Analysis of the results obtained shows that in approximately 90% of the cases investigated, power distribution system objects are sources of significant levels of power supply frequency electromagnetic radiation (its magnetic component, in particular).

Tests with the EMR-20 in the vicinity of radio and TV transmitters

We measured the electromagnetic radiation in the vicinity of the Moscow TV and FM broadcasting centre in Ostankino. Using a spectrum analyzer, we determined that the major RF sources were in the VHF range (30 to 300 MHz). We therefore performed the measurements using the EMR-20 with a calibration factor $k = 1$, because only a low radiation level was expected (below 10 V/m).

The standard we used for this high-frequency range is “The sanitary regulations and norms for protection of the population of Moscow City from electromagnetic fields generated by transmitting radio engineering objects” (1996). This official document defines limit values for RF radiation from 30 kHz to 300 GHz and also specifies a measurement method. It provides for the following frequency ranges: 0.03 to 3 MHz, 3 to 30 MHz, 30 to 300 MHz and 0.3 to 300 GHz. The limit values are shown in the table.

<table>
<thead>
<tr>
<th>Limit values for frequency ranges</th>
<th>0.03 to 3 MHz</th>
<th>3 to 30 MHz</th>
<th>30 to 300 MHz</th>
<th>0.3 to 300 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>V/m</td>
<td>V/m</td>
<td>V/m</td>
<td>µW/cm²</td>
<td></td>
</tr>
<tr>
<td>1. Urban area</td>
<td>15.0</td>
<td>10.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>2. Workplace</td>
<td>15.0</td>
<td>10.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>3. Public areas</td>
<td>10.0</td>
<td>7.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

The limit value for the case named above (VHF range) is 2 V/m, this was slightly exceeded at some places within the dwelling that we investigated.
The main difference between the standards applied in Russia (and other countries of the former Soviet Union) and those valid in other countries is in the method used to determine the maximum electromagnetic radiation exposure. This is mainly due to the different criteria used to assess the biological effects of such radiation. The maximum permitted value is the main criterion used for fixing the electromagnetic radiation exposure in the Russian standards. The radiation exposure must not adversely affect, even momentarily, the human homeostasis (re-establishment of internal balance) including the reproductive function. In addition, no protective, adaptive or compensatory biological mechanisms should be activated on either a short- or long term basis. The daily radiation dose from a given source may not result in any illness or health hazard that exceed an adaptive reaction and which can be identified by modern research methods during or after exposure, regardless of sex or age. The maximum permitted value results from this; in practice it is a fraction of the minimum value of the EM field that can cause a reaction.

Fig. 3. Distribution of magnetic flux density in the room. The source of the magnetic field is a power supply switchboard in an adjacent room.

Fig. 4. Distribution of magnetic flux density in the room. The source of the magnetic field is a transformer substation.

Fig. 5. Electric field strength measured in a private flat using the EMR-20. The source of EM radiation are antennas of radio and TV transmitters in Ostankino (Moscow).
H-field Measurements in the IC-2000

H-field influences in double-decker coaches and in the track area

Increasingly in modern trains, more and more appliances are being installed to bring about greater performance and comfort. The growing need for such devices compels designers to locate strong magnetic field sources, such as transformers, interphase transformers and high-voltage power cables in areas which are susceptible to interference. Sensitive areas are electronic cubicles in the trains or safety devices along the track. Another peculiarity typical of railways is the single-phase power supply system (outgoing and return conductors situated far apart from one another) which allows the generation of uncompensated fields. The passenger coaches of modern passenger trains, likewise, are increasingly exposed to strong magnetic fields. These require particular attention, as the conditions for people with pacemakers, at the least, must be complied with.

Measurements in the passenger compartment
The measurements were intended to provide information about potential magnetic field sources, the characteristic of the magnetic field over time and the intensity of the exposure. As extremely influential magnetic field sources, the bus bar of the train in the floor of the lower deck (electric power supply for the entire train) and the contact line were in the foreground. The requirements for the measuring instruments were as follows:

- Automatic measurement with accurate recording of measured values
- Evaluation of field axes and frequencies
- Frequency sampling rate at least every 5 seconds, in certain cases up to 3 values per sec.
- Transferability of measured data to PC in common data formats; simultaneous evaluation of the results from several instruments must be possible with the PC.
The above conditions led us to use three EM field analyzers type EFA-3 and EFA-2 from Wandel & Goltermann.

The evaluations of the measurements produced the following results:

Value while setting up the train: 22 µT
Value during operation: 9 µT. In the top deck, the influence of the contact line is dominant, in the lower deck the influence of the train bus bar.
Precautionary value: 100 µT (values are far below this).
As expected, the magnetic field characteristic was discontinuous. The graph shows a typical characteristic of the magnetic field with the associated current values.

Measurements taken around the track were intended to provide information concerning the strength of the magnetic field generated by the train bus bar. Conditions in the area of the rails are extremely complex. The fields of the rails carrying reverse current overlap the fields of passing trains.

For measuring the electrical inter-
ference of apparatus, the sum total field is the decisive factor. For a precise assessment, the signals have to be recorded in a transparent manner and evaluated with the aid of plotters or oscilloscopes.

A parallel measurement using the EM analyzers of Wandel & Goltermann with an external probe in the area of the rails raised the following questions:

- Can the rail currents be measured simply using the WG probe, without contact and with no need for complicated apparatus?
- Can this simple measuring system be used to produce standard H-field characteristics for the rolling stock?
- Is a sampling rate of 3 measured values per second sufficient?

Is remote control via PC worthwhile for hard use in the field?

The evaluation produced the following results:

- Up to train speeds of 40 km/h, a simple rail current including H-field train profile can be measured using one instrument.
- At higher speeds, the instrument at least permits conclusions to be drawn (with exact recording of measurements) with regard to rail currents.
In the Work Environment of modern Induction Furnaces
Measurements of electromagnetic fields in industrial plants

The potential harmful effects of electromagnetic fields on the human organism are now subject to regulations and standards which define the requirements for personal health and safety at home and at work. Whereas numerous limit values have been determined for the actual fields, applicable definitions for measuring procedures and radiation exposure are still lacking, particularly where occupational safety is concerned. This report puts forward proposals for ways to approach this problem. It provides examples of measurements of flux density in alternating magnetic fields, which were conducted in the work environment of industrial induction furnaces. The results of the measurements are confirmed by calculations which also help to illustrate the typical magnetic fields of these induction furnaces. The influence of specific furnace designs on the stray magnetic field is demonstrated by means of two furnaces of almost identical size. Finally, there follows a description of the measuring systems employed: a simple 100 cm² standard coil connected to an RMS voltmeter for anisotropic measurements, and a digital field analyzer with an isotropic 3D probe.

The stray magnetic fields outside these induction furnaces are extremely inhomogeneous, but are generally sinusoidal on a single-frequency, in line with the induction currents. Their values decrease considerably the greater the distance from the source.

Measurements of the magnetic field on the platform of a medium-sized induction furnace MFTGe 3t / 1.6 MW / 250 Hz
Field experts of the Institute for Electrical Machines at the Technical University of Aachen [2] have conducted a systematic study of the magnetic field on the platform of a medium-sized induction furnace type MFTGe 3t / 1.6 MW / 250 Hz (Figure 1). The measurements were carried out at three different heights: at 0.9 m, 1.25 m and 1.55 m above the reference points marked on the platform of the furnace (Figure 1). The values determined at a height of 0.9 m are represented as iso-induction curves. Their course is not coaxial to the coil due to the influence on the platform of metallic objects in the proximity of the furnace and due to the strong currents feeding the coil (Figure 1). The values measured at 0.9 m between reference points A and A’ in Figure 1 were entered in a graph with values which were calculated with the aid of 2D and 3D simulation (Figure 2). The 3D calculations clearly match the test results, whereas the 2D calculations produce somewhat higher values. The graph also shows that induction diminishes with the distance from the coil. It must be noted at this point that only the values in the accessible area are relevant for measuring the possible radiation exposure of personnel, and that this zone commences at point A. In order to clarify the relationship to existing or proposed limit values, the following limit-value curves for the operating frequency of 250 Hz were incorporated in the graph: $B_{\text{lim}} = 320 \mu T$ according to Standard ENV 50166 and EU Proposal [3].
BAL1 = 40 µT (action level 1)
BAL2 = 80 µT (action level 2)
BAL3 = 128 µT (action level 3)

The induction values in the work area lie far below B\text{lim}, sufficiently below action levels 2 and 3 and, at a distance from the furnace cover of 0.5 m or more, even below action level 1.

**Magnetic fields from two box-shaped furnaces of similar size but different design**

Measurements carried out on two box-shaped 1000 Hz furnaces of almost identical size (1.0 t and 1.2 t loading capacity) for aluminium bronze revealed the enormous influence of design features on the shape and size of the stray field (see Figure 2). Both furnaces project beyond the operator platform by approx. 50% of the size of an operator. The stray magnetic field in the operating area of furnace A), with a nominal capacity of 450 kW and without a magnetic screen, reaches values of between 300 µT and 3300 µT, which considerably exceed the relevant limit value $B_{\text{lim}} = 80 \, \mu\text{T}$ to ENV 50166, not to mention $B_{\text{AL3}} = 32 \, \mu\text{T}$, action level 3 of the EU Proposal [1].

On the other hand, the corresponding values for furnace B) with a nominal capacity of 500 kW, lie far below these limit values at 10 µT and 63 µT. The measurements were conducted using two different measuring systems, for which 100 cm$^2$ coils were employed in each case:

One of the systems used an anisotropic measuring probe, a simple 100 cm$^2$ flat coil connected to an RMS voltmeter. This permitted the measurement of a single axis. The probe had to be rotated until the position where the maximum reading was obtained was found. At a frequency of 50 Hz, 1 V\text{RMS} on the voltmeter corresponds to an average field density of 1 mT in the coil. At other frequencies, the value obtained must be multiplied by the factor 50/f/Hz.

The other system used an isotropic probe with an analyzer [2] featuring a digital readout and storage capabilities for the date, time, frequency and all three measured values. The savings in time and improved reliability justify the expense of the system after just a few test series. However, the operating range of the EFA-2 system from Wandel & Goltermann was insufficient with regard to the field values in the furnace without a magnetic screen, which exceeded the relevant limit values. Fortunately, the simple anisotropic system was available to complete the measurement. The results portrayed in Figure 2 confirm the extent to which the results from the two measurement systems matched up.

The measured conditions are represented by the calculated magnetic fields (field curves) and the ISO-induction curves (see Figure 2) in a convincing manner. It is evident that the lack of magnetic screens gives rise to a much larger stray field than is the case with a screened furnace.

**Bibliographical references**


Magnetic fields below the operator platform of heavy-duty induction furnaces with automatic loading systems and fume extractor

Today, large heavy-duty induction furnaces without extensive auxiliary equipment such as automatic loading systems and fume extractors are unimaginable. Operation is largely automated. Consequently, employees do not need to remain in the proximity of the stray field. What is important here is the assessment of relevant radiation exposure conditions in the work area, as the field distribution differs greatly depending upon the layout of the auxiliary equipment.

Measurements were taken at typical points – numbered accordingly – at which operators might occasionally stand. The highest induction values which were obtained during a typical smelting cycle lay far below the relevant limit value $B_{ex} = 320 \, \mu T$. 

Figure 1

Figure 2 (Reproduced from original documents)

Figure 3
Electrosmog in Hospitals and Doctors Surgeries?

Potential sources of danger are often unknown

Equipment in hospitals and surgeries is intended for the benefit of people’s health. However, one often overlooks the fact that the electrosmog generated by some appliances represents an unnecessary health hazard for their operators.

Effects on health

Patients and health service personnel are thus exposed to considerable magnetic fields, in NMR tomography, for example. These direct-current magnetic fields, which are a feature of the technology in use, may lead to feelings of ill health once they reach a certain strength. The influence of strong magnetic fields upon human ECG curves is also medically proven. The extensive consequences of these non-thermal effects are being discussed in medical scientific circles.

The general practitioner is aware that diathermy units employed for partially warming the body and accelerating the healing process work with high-frequency electromagnetic fields. In extreme cases, the thermal effect of electromagnetic radiation can lead to intense heat—so-called “hot spots” in the tissue—and even to actual burns. Besides this acute damage, lower temperatures can also represent a hazard, above all, for people who are exposed to high-frequency fields for a long period.

Monitoring the limit values

In the discussion on consequences for health, however, it must be borne in mind that the effects of electromagnetic fields on humans depend upon their intensity and frequency. Therefore, appropriate limit values for human safety have been defined by national and international bodies.

On the other hand, measurements on diathermy units, for example, have disclosed that the recommended limit values are not complied with in the direct vicinity of a machine. Even at a distance of one metre, the limit was still exceeded tenfold. Only from a distance of approximately two metres does the level of electromagnetic exposure conform to the relevant limit value. Nevertheless, safety distances for personnel are no more enforced by law than is the monitoring of limit values. Therefore, the principles of initiative and prevention are of primary importance here; i.e. conformity with the recommended
limit values should be monitored even without legal obligation to do so. Wherever possible, sources of hazardous electromagnetic fields should be avoided or minimised. This also applies in particular to hospitals and doctors surgeries, which occupy a special position in the alternating field between sickness and health.

**Interference to sensitive equipment**

In addition to the direct risk to health posed by electromagnetic fields, people are also exposed to an indirect risk: Equipment such as an ECG or an electronically controlled drip may malfunction as a result of electromagnetic fields, thereby giving rise to situations which may at times be lifethreatening. Furthermore, patients with pacemakers, for example, are also endangered by electromagnetic radiation which, in the worst case, may cause these devices to fail.

The ban on mobile phones in hospitals clearly demonstrates how sensitive this area is. The electromagnetic waves emitted whilst telephoning can impair sensitive equipment in the hospital as well as the pacemaker of a patient. However, if one compares the mobile phone, which functions at 2 watts, with diathermy units, which have an output of 500 watts, it becomes clear which sources of danger are being completely ignored.

Since magnetic fields penetrate virtually all materials, even reinforced concrete walls and ceilings, the selection of the best location for an NMR tomograph, or a hyperthermy or diathermy unit, is a matter of considerable importance. The machines should be erected in a place where there are no patients in direct proximity, including in neighbouring rooms or on adjacent floors. Only in this way can electromagnetic exposure of the body be kept to a minimum. Moreover, when selecting locations for such equipment, care must be taken to ensure that no sensitive devices are nearby. In this case, too, measuring instruments should be used to examine how high electromagnetic exposure levels are and how this could give rise to interference. Furthermore, the general power supply to the hospital must also be taken into consideration, as this can also disturb the function of electronic equipment. Here, the important thing is to situate equipment, especially ECG and EEG units, far from the central power supply lines. Rooms containing such equipment – and this applies to GPs surgeries and rooms used for home dialysis as well as to hospitals – should be screened against power installations (regulated in DIN VDE 0107).

**Sensitive measuring instruments, such as those used in intensive care units, should not be located near to the route of central power supply lines.**

**Protective measures at little expenditure**

Even though the possible effects of electromagnetic fields on health have not yet been fully researched, small steps can already be taken to avoid potential danger sources. Protective measures which can be taken frequently involve little effort and expense. In many cases, marks indicating the minimum distance from a device during its operation, or alterations such as moving a machine to a different location, may already suffice. Furthermore, warning signs pointing out possible risks to patients with pacemakers should become standard. However, before such protective measures can be taken, the potential danger sources and electromagnetic exposure levels in their vicinity first have to be known.
Safety at Work
The EMF measuring service of the employers’ liability insurance association for precision mechanics and electrical engineering

“Cologne. Recently, in addition to the already established measuring services for determining noise conditions and exposure to pollution at the workplace, the employers’ liability insurance association began providing a further highly topical and urgently needed measuring service: the determination of exposure to electric, magnetic and electromagnetic fields.”

This, or something similar, was what appeared in the newspapers over the last few months. But what is actually behind this new measuring service?
Its objective, above all, is to offer a qualified measuring service in the area of field measurements to those insured by the employers’ liability insurance association for precision mechanics and electrical engineering, as well as to those insured by other such associations and those with personal accident insurance. This new service is also available to all interested parties, however.

The need for such a measuring service has evolved due to the fact that the generation, transmission, distribution and consumption of electrical energy and its use in the transmission of signals in telecommunications is closely associated with electric, magnetic and electromagnetic fields. The resulting exposure, particularly at the affected workplaces, must be considered as an environmental factor in the issue of occupational safety.

Areas of application which give rise to fields are present in industry in the most varied situations. For example, static fields occur during electrolysis and in electroplating. Medicine makes use of high static fields in magnetic resonance (MR) tomography and spectroscopy.
The low-frequency range from 1 Hz to 30 kHz is the range used by broad sections of industry, e.g. metallurgy, induction heating, welding or even demagnetisation. Of course, all electrical energy supply and distribution (50 Hz) also lies in this frequency range, as does the supply and distribution of power for railways (16⅔ Hz).

However, the high-frequency range - above 30 kHz - is also often employed in industry. Whereas inductive processes tend to use the low-frequency range, capacitive applications such as wood drying and veneer processing or the welding of plastics also generate high frequencies.

One extensively used process is induction hardening, with both low and high-frequency fields. Lastly, a further industrial application is the microwave (2.45 GHz), which is used for drying and curing in the manufacture of rubber.

This brief list of applications demonstrates how widespread the use of fields is in our working environment. All the more reason why we should ensure safety at workplaces with exposure to electric, magnetic or electromagnetic fields.

In the interests of occupational health and safety, the committee of experts for electrical engineering determined rules for workplaces as early as 1982, and these are set out in the electrical engineering rules of Standard DIN VDE 0848, which apply to Germany. In 1995, these were revised and brought into force as the “Rules for the protection of health and safety at workplaces with exposure to electric, magnetic or electromagnetic fields (MBL 16)”.

In addition to limit values, these rules also contain instructions on measurement and the
assessment of measured values. An accident prevention regulation dealing with fields is currently in preparation. This confirms the need, both of employees with accident insurance and employers, for the creation of a legal basis for occupational safety.

The “EMF measuring service” sees its primary task as
• The measurement of workplace-related field strengths
• The assessment of measured values in accordance with currently applicable standards
• Advising businesses.

A large variety of modern measuring instruments is available for measuring the very wide band of frequencies from 0 Hz to 40 GHz. One of these instruments, which covers the frequency band from 5 Hz to 30 kHz, is the field analyzer system EFA-3 from Wandel & Goltermann. This very robustly designed measuring system features excellent characteristics for measuring exposure at the workplace. During our search for a suitable measuring system, the following properties formed the most important criterion for our decision:

• The precision of isotropic measuring probes for magnetic and electric fields
• The compact design – vital with regard to transport and ease of carrying
• User-definable filter
• Simple operation
• and the possibility of storing technical data so that it can subsequently be used on a PC.

The filters, in particular, which are set for certain frequencies but can be freely defined by the user, enable the correct assessment of fields in industrial applications. A few weeks ago, for example, measurements were carried out to determine exposure at different points in the vicinity of an extremely powerful converter plant (nominal output 100 MW, frequency 16\(^\frac{2}{3}\) Hz / 50 Hz). This measurement showed that not only did the fundamental frequencies 16\(^\frac{2}{3}\) Hz and 50 Hz contribute considerably to exposure levels, but also the harmonic waves at 33\(^\frac{1}{3}\) Hz and 100 Hz. Thus, near the transformers a magnetic flux density of 3.3 mT was measured at a frequency of 33\(^\frac{1}{3}\) Hz. The permitted value in exposure zone 1, at 2.04 mT, is greatly exceeded. This area therefore suffers from increased exposure, and as such, the permitted value of 3.82 mT must be applied and the time spent in this area restricted to two hours a day.

If we had only measured the fundamental frequencies in this case, we would have come to fully the wrong conclusion, since these exposure levels were by far within the permitted range and even clearly below the lower values of exposure zone 2. With field measuring instruments which only measure the broadband, do not indicate the dominant frequency and are unable to filter different frequencies individually, correct assessment would not have been possible. In contrast, however, the EFA-3 field analyzer from Wandel & Goltermann proved to be a well-equipped, user-friendly and reliable instrument for field measurements.
Safety in Transmitting Stations

Training and check measurements as the first step

One of NTL’s roles in the UK is the responsibility for operating the independent UHF TV broadcast transmitter network for Channels 3, 4 & 5, plus most of the independent broadcast radio systems, both MF and VHF. Our many hilltop sites also carry other systems (NTL & non-NTL) on their masts and towers, covering the whole range of powers and frequencies.

As a result of the RF concentration on our sites, we have had to develop methods of ensuring staff safety, particularly for climbing staff. This includes our customers and suppliers staff who need access to our structures, as well as our own engineers, technicians and riggers.

Good working practice, staff training & awareness, and careful control procedures are the primary means for ensuring this safety. However RF instrumentation is also an important element. Over the past two years we have introduced the widespread use of personal RF monitors to support our methods.

We realised that they are not a “magic” solution and should only be used with care by trained staff. We normally work in the “near field” RF environment and unless staff have at least a basic understanding of the physics of RF and the meters, then the benefit of using them can, in our view, be lost. We have therefore developed an internal training scheme for all our climbers.

As a back up to the personal monitors we have recently equipped several teams with EMR meters from Wandel & Goltermann. These precision RF meters are intended for use by fully trained engineers to survey areas where experience or personal monitors indicate a potential safety problem.

We managed to carry out an “unplanned test” of an early EMR-20 by accidentally dropping it from about 200 m from our Black Hill mast in Scotland. The strong design ensured that only a minor repair was needed! The instruments are compact, easy to use and robust. The auto zero is especially

It is important for maintenance personnel working on RF antennas to carry a warning and measuring device with large frequency and dynamic ranges.
valuable in our constant RF environment. The built-in alarm is reassuring and simple to adjust, and the two-year calibration period means lower running costs and less downtime. Attention to detail is important and the weatherproof design and the standard batteries are appreciated by our users.

The later EMR-30 and EMR-300 models that we use still have the same advantages but have added features such as data logging and interchangeable probes. These are particularly useful for more detailed surveys, which are often undertaken in unfriendly environments on exposed structures. The WG EMR range represents the best current solution for our particular application.
The Facts must be known
Interview on real EMF dangers and limit values

James B. Hatfield, P.E. is a partner in the firm of Hatfield & Dawson Consulting Engineers Inc. which is established worldwide in the design, analysis, adjustment and measurement of MW, VHF, UHF and microwave antenna systems. They have been involved in projects in Poland, Armenia, United Kingdom, Taiwan, etc. Determining compliance with federal and local RF safety guidelines are a major activity of Hatfield and Dawson. J. Hatfield has written several papers and articles on the subject and delivered a series of papers at meetings of the NAB, IEEE Broadcast Technology Symposia, American Society of Civil Engineers and at Wireless Buildout Conferences, etc. A description of RF compliance issues from a consulting engineers perspective follows.

Why is EMF so important for you?
There is a perception of hazard on the part of some members of the general public from exposure to RF fields from antennas that have brought to their attention at locations of high visibility. We have been called upon by federal and local governmental agencies and private companies to provide expert testimony at various land use hearings and other public forums. There is a general misunderstanding of the science behind RF safety standard setting on the part of the public that can only be addressed by education of those concerned. I am a member of IEEE SCC28 and its five subcommittees and, as such, am actively engaged in the standard setting process. We provide consultation to public agencies and private companies to help them grapple with the issues of compliance with new ANSI, FCC and local EMF regulations.

Can it be said that there are certain critical situations in which possible danger exists?
RF safety standards are set between 10 and 50 times lower than demonstrable biological effects. The issues of standards compliance and danger are separate and distinct. The greatest hazard that we normally deal with is that of RF shock and burns from induced RF energy from MW antennas in large cranes. Actual hazards may
exist in close proximity to broadcast FM and TV antennas, high power, base insulated LF & MW towers, RF heat sealers and in the main beam of high power microwave and radar antennas.

What recommendations would you give to companies where EMF exposure is a problem?
The FCC requires licensees of facilities at antenna farms and other multiple emitter sites to cooperatively resolve situations where the human exposure to RF fields exceeds FCC maximum permissible exposure (MPE) standards. In complicated situations measurements are advised. At simpler installations computations may suffice for the determination of compliance with the MPE.

What demands do you make of measuring equipment used for stage 2, pre-qualification?
In an multiple emitter situation where many different frequencies are radiated a conformal probe is the only practical solution. The meter must also respond properly to multiple frequency fields without exaggerating or minimizing the measured values. The probe should not have spurious responses at out of range frequencies. It is also desirable to have the meter automatically apply the calibration factor to the readings.

How do you handle situations where regular over-exposure is likely?
Areas of exceedance must be appropriately marked and signed. Power may have to be reduced when towers and other antenna support structures are climbed. RF protective suits are a good solution in some situations.

How does Wandel & Goltermann fit into this environment?
The meter is compact and easy to carry on a trip in a brief case. The response at MF is the best in the industry in terms of accurate electric field readings for AM stations. The magnetic field meter has a nice dynamic range for determining compliance with the FCC magnetic field MPE. The WG meters are well built, light weight, and easy to operate.
Measurement of the Electric Field of a Scanning Radar Antenna

Using the EMR 300 and Probes 8 and 9

For a long time now, the measurement of high-frequency pulsed electromagnetic fields, such as those generated by scanning radar antennas, has been an unresolved problem. Since radar transmitters predominantly generate very high peak microwave power, this type of measurement is of special interest due to the possible biological effects of such pulses on humans.

The Dept. for Radio Communications and Microwave Engineering at the University of Zagreb, Faculty of Electrical Engineering and Computing, received a request to conduct measurements on a radar transmitter at Zagreb Airport. The radar in question is an L-band type (operating frequency 1.3 GHz) used for air-traffic control. Usually, measurements are carried out when the radar antenna is stationary (“static case”), which is advantageous in that it permits the use of thermocouple detectors, which show a true rootmean-square (RMS) value. Unfortunately, this was not possible in this case, as the operation of the radar could not be interrupted. We decided not to attempt measurements using detectors containing thermocouples because of their sensitivity to temperature fluctuations and to...
short-term or minor overload. Moreover, these detectors are too slow (typical response time 1 s) and too insensitive to measure rotating radar pulsed fields at distant locations. Therefore, our principal task was to find measuring equipment capable of performing these measurements.

As the first step, we tried to characterise the ideal device for performing such measurements.

The first requirement is certainly an immediate response (~1 µs or less).

The second prerequisite is that the peak values of electric fields should be indicated for dosimetric purposes. The instruments should therefore have a high dynamic range (40 dB or a ratio of 1:100, because the peak electric field in our case, for example, could be 33.5 times greater than the RMS value). The peak values were required for the purpose of comparison with standards and guidelines (ENV-50166-2, IRPA/ICNIRP). The new European preliminary standard ENV 50166-2: “Human exposure to electromagnetic fields - High frequency (10 kHz to 300 GHz)” (CENELEC, 1995) sets the limit value for pulsed fields as a peak value of an electric field strength (V/m). Chapter 5 of the IRPA/INIRC guidelines, “Guidelines on limits of exposure to radio-frequency electromagnetic fields in the frequency range from 100 kHz to 300 GHz” (1991) determines the value for a peak electric field as an equivalent plane wave field strength averaged over the pulse width which should not exceed 32 times the field strength limits for the continuous wave case.

The third characteristic is that of ensuring a field isotropic response, i.e. the antenna system should consist of three dipoles (if measuring an electric field).

The final property is optional, as it depends upon the distance from the source. If the measuring point is in the near field then both fields – electric and magnetic – should be measured isotropically. In this case, the simple relationship between the electric field, power density and free space impedance no longer holds true. Here, both sensors (for the electric and magnetic fields) must be small compared to the wavelength (~λ/10).

Nowadays, most EMF measuring equipment uses either diodes or thermocouple detectors. To the best of our knowledge, diode detectors, showing the peak value of an electric field, have not yet been used for measuring high-peak short pulses. This is due to the fact that the diode detector acts as a linear detector at higher levels: the output voltage is proportional to the input voltage. This property, in combination with the integrated circuits of an instrument, indicates a value other than the true RMS and must be corrected using sensor data.

Finally, measurements could always be performed using a spectrum analyzer and a broadband antenna.
However, this solution is rather inconvenient. The solution offered by W&G certainly represents one of the best on the market. The EMR-300 with two electric field probes (types 8 and 9) has already established itself in the measurement of continuous-wave high-frequency fields. Both probes are based on a diode detector with integrated circuits. Therefore, in order to measure the peak values of pulsed fields, the values displayed by the instrument have to be compensated. This is achieved with the aid of corrective curves. The basis for the curves is a knowledge of the four parameters of a radar transmitter: pulse width, pulse repetition frequency, aerial rotation speed and antenna beam width. If these parameters are known, the value displayed by the instrument can be scaled to the actual irradiated peak value of an electric field pulse. One has to read the value displayed by the instrument and multiply it by this “beam factor”. Unfortunately (or rather, fortunately for me), W&G was not in possession of such a curve for a radar with characteristics like ours in Zagreb (the parameters: PD = 3.3 μs, PRF = 340 Hz, aerial rotation speed = 5 rpm and antenna beam width = 1.2°). Therefore, I accepted a kind invitation by Mr. Hans Förster, without whom the EMF group in WG would not exist, to produce the necessary curves myself. There, in Eningen, surrounded by beautiful, peaceful countryside, I met the whole team composed of engineering and marketing geniuses. So, the result of my enjoyable stay are corrective curves of the probe types 8 and 9 for the radar in Zagreb (Fig. 1). Of course, the first thing I did upon my return to Zagreb was to conduct measurements on the radar. I measured the field at a distance of 150 metres from the radar transmitter station. For the measurements, I used probe types 8 and 9. The results were fascinating: even though the displayed values differed by approximately 28 %, the compensated peak field values of both probes, with a difference of approx. 0.4 %, were almost identical (Table 1).

In conclusion, it appears that the previously unsolved and complex problem of measuring electric fields generated by a scanning radar antenna has been solved by W&G, who have provided an almost ideal solution.
Precision for any Place in the World

The built-in quality of EMF measuring instruments from Wandel & Goltermann

The measuring instruments from Wandel & Goltermann for electromagnetic fields measure with precision, even under extreme environmental conditions and over long periods. In this way, they offer a high degree of measuring accuracy – an indispensable criterion where the protection of people is concerned. In order to ensure this high level of quality, the instruments must undergo stringent tests during their design and production. Every single circuit element is tested in-circuit to ensure correct component insertion, soldering and faultless operation. Only then is the printed circuit board released for assembly in the instrument.

A look inside the device reveals an exemplary construction with double-sided SMD placement. Special screens guarantee resistance to spurious irradiation. Those wishing to monitor diathermy units, for example, or microwave applications, require measuring instruments which can withstand such high field strengths and, even more importantly, continue to show reliable test results under these conditions. For the purpose of comparison: domestic appliances must have a resistance to spurious irradiation of 3 V/m, while industrial machines are tested at 10 V/m and motor vehicles at 80 V/m. The limit value for the protection of people in their working environment and at medium frequencies lies at 61.4 V/m. The EMR measuring instruments from Wandel & Goltermann are designed to cope with many more times that figure: 1,000 V/m.

One secret behind such resistance lies in special substrates and the design of the sensors; another is the aluminium coating of the plastic housing. This also explains the relatively low weight of the instruments, which can only be advantageous during daily use.

Of note here is the very broad measuring range of each instrument. This, in turn, places great demands on their design. EMR field strength measuring instruments, for example, have a dynamic range of 60 dB. Such a
The burn-in process to which every instrument must be subjected has a passive and an active phase. During the passive phase, an increased outside temperature is simulated. In the active phase, this is joined by the heating up of the switched-on unit with raised temperatures in the interior.

The device remains in the burn-in chamber for several days, and is exposed in cycles to different ambient temperatures: 20 hours at +50 °C and 4 hours at +23 °C. The above process pre-empts the failure rate of the first year and is equivalent to running in an engine. After burn-in, the test results are more constant. And the instrument must only be calibrated after the relatively long period of two years. For the user, the instrument therefore has the advantage of high availability coupled with low running costs.

In order to ensure quality, the measuring instruments are not only exposed to heat. Environmental tests anticipate extreme situations such as those which occur after changing from warm rooms to a cold outdoor environment. The devices are stored at temperatures of -40 °C and +70 °C and then undergo a function test. During operation, they must withstand temperatures ranging from 0 °C to +50 °C, which means that they must display accurate results under these conditions. The humidity test entails 96 hours of exposure to +40 °C and 95% air humidity, which is equivalent to the climate in a tropical rain forest.

Only then is a measuring instrument from Wandel & Goltermann sent on its way to the customer. It is fully equipped to cope with the stresses of transport, too. Drop tests during the design stage ensure the sturdiness of both the housing and interior components. In this test, the device is literally dropped – twice onto each side of the housing, i.e. twelve times in all – and this from a height of up to one metre. In addition, the breaking strength of the plastic housing is tested once more by cooling the device to -40 °C followed by another drop test. A typical situation during daily use for measurements illustrates the reasons behind this test. Let us assume that the instrument is stored or transported at temperatures well below zero. The user picks it up and accidentally drops it. Normal plastic would be brittle at such extreme cold and would break, whereas the housings of W&G instruments, constructed of special plastic, would withstand this situation, as proven by the above drop test.

Additional vibration and shock tests simulate rattling and shaking during transport. The vibration data is set at 9–200 Hz at 20 m/s², then 200 to 500 Hz at 40 m/s². This is followed by 3,000 shocks at 250 m/s². The total test time is approx. 3 hours.

When the customer finally has his hands on his EMF measuring instrument, he has at his disposal an electromagnetic field measuring system produced by a company which works with a quality management system certified to ISO 9001 and manufactures in accordance with the ecological guidelines of ISO 14.001. It bears the CE mark and withstands environmental conditions from around the globe.