SENSORS FOR LOW FREQUENCY ELECTROMAGNETIC RADIATION

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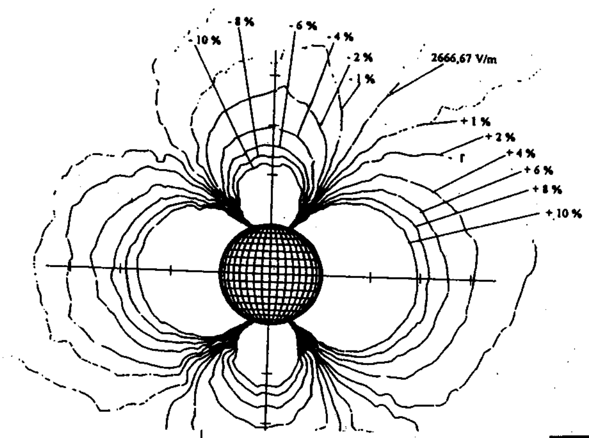
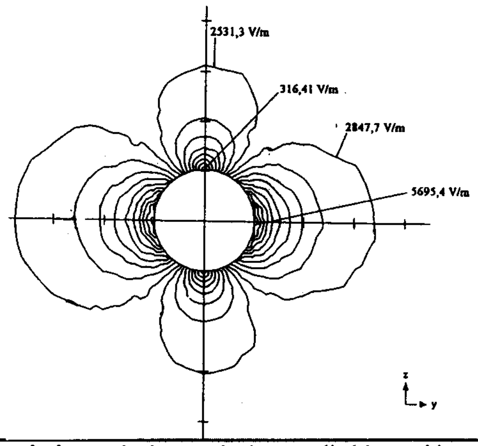
INTRODUCTION

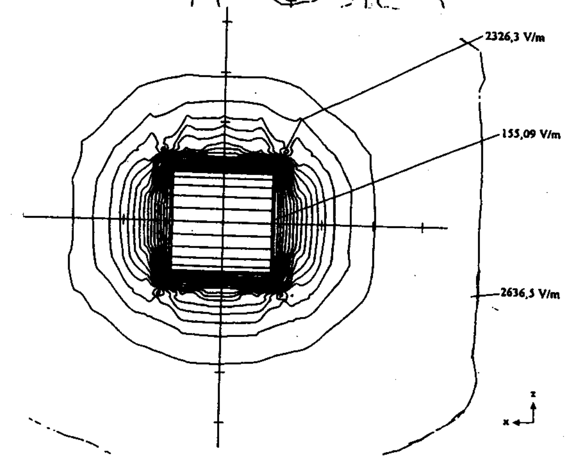
For estimating the personal exposure from low frequency electric and magnetic fields suitable measurement systems are necessary. Investigations of appropriate magnetic and electric field probes and sensors have been done as a basis for a pocket sized personal dosimeter. There exist many different sensors, which can be used for the measurement of static and low frequency magnetic fields, such as inductive transducers, hall generators, tunnel diode oscillators, flux gate sensors and magnetoresistive sensors. In contrast to the magnetic sensors there are less different sensor types based on different physical detection principles available showing a sufficient sensitivity for low frequency electrical fields. Important is the knowledge on the feed back of the sensor itself on the detected field strength. Whether a sensor is suitable for a certain application is depending on its frequency related sensitivity, its signal to noise ratio, linearity and detection range, sensitivity to environmental influences as temperature, humidity etc. This presentation will focus on some important basic aspects of the measurement of low frequency electrical and magnetic fields for radiation protection purposes.

ELECTRICAL FIELD: DETECTOR GEOMETRY INFLUENCES ON THE UNDISTURBED FIELD

By means of analytical and numerical (1) investigations feed back effects on the undisturbed electrical field have been investigated. The results are presented in the following examples of three different sensor geometries, spheres, cylinders and cubes (Fig. 1)





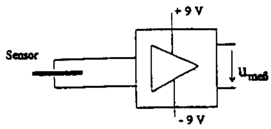


undisturbed electrical field 2,667 kV/m	spheric geometry r = 1 cm	spheric geometry r = 2 cm	cylindric geometry r = 1 cm	cubic geometry a/2 = 1 cm
	analytical	numerical	numerical	numerical
maximum field in kV/m	8,0	9,1	10,9	9,8
field in kV/m x=0, y, z	8,0	9,1	10,9	9,8
field in kV/m x=5 mm, y, z	6,9	5,9	6,0	5,4
field in kV/m x=10 mm, y, z	3,5	3,3	10,9	9,8
field in kV/m x=20 mm, y, z	2,8	2,9	3,0	3,0
field in kV/m x, y=0, z	2,7	3,1	3,1	3,0

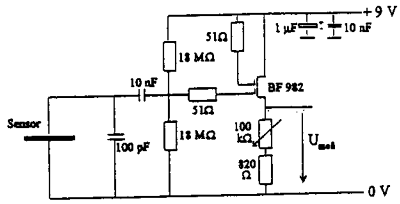
Fig. 1: Feed back of different sensor geometries on the undisturbed electrical field (the origin of the x,y,z - coordinate system is the geometric center of the object)

ELECTRICAL FIELD: EXAMPLE FOR THE MEASUREMENT, INFLUENCED CHARGE METHOD

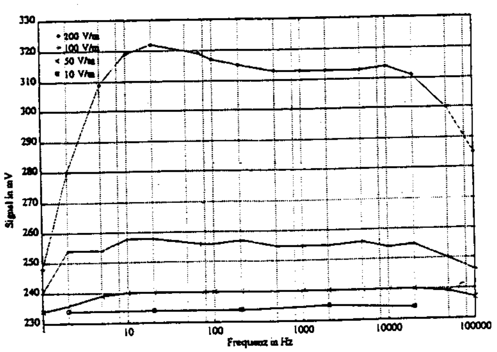
There are different detection principles for electrical fields such as the measurement of induced electrical charge, induced coulomb force on charges, deviation of electron beams, piezo-effect, electro-optical effects (Pockels-, Kerr-Effect), modification of the gate to source voltage of field effect transistors by induced charges etc. There is a big spectrum of different electronical implementations resulting in different sensitivities and frequency responses of a sensor. The following examples show two possibilities for the measurement of induced charges on a capacitive sensor, a differential amplifier circuit and a field effect transistor circuit (2, modified). They show differences in detection efficiency and frequency dependence (Fig. 2).



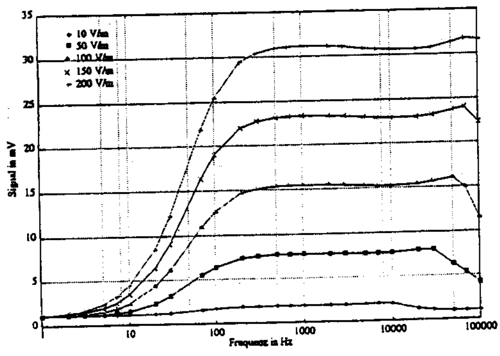
capacitive sensor 72 mm diameter, 125 pF



capacitive sensor 72 mm diameter, 125 pF



without electrical field: 1,1 mV



without electrical field: 233 mV

Fig. 2: Frequency dependent sensitivity of given sensors detecting induced charges on a capacitive sensor using
a) a differential amplifier circuit (left) and
b) a field effect transistor circuit (right)

Electrical field strengths of 0, 10, 50, 100 and 200 V/m and frequencies varying from 1 Hz to 100 kHz have been applied. There is a small lower frequency detection limit for the differential amplifier version, which can be varied by modification the amplifier entrance circuit. The entrance capacity reacts as a frequency dependent short circuit resulting in a frequency depending loss of sensitivity. The linearity of the sensor signal is poor. The absolute sensitivity of course depends on the effective area, where electrical charge is induced.

When field effect transistor circuits are used (Fig. 2 b), there is a higher detection limit at lower frequencies. The limiting factor for the lower frequency limit is the resistance R_E, which was chosen to be 18MΩ. Higher nominal values for R_E often have been found to show lower resistance's as indicated. In addition air humidity and resulting current losses become important and result in instable circuit conditions. To increase the sensitivity the parallel capacitance, which is 100 pF in Fig. 2b, has to be increased. As a consequence the lower frequency limit increases also. It is a question of optimisation on the application conditions, what is best.

MAGNETIC FIELD: DIFFERENT SENSOR PRINCIPLES AND THEIR APPLICATION RANGE

The following sensors for the measurement of static and low frequency magnetic fields have been investigated: inductive transducers, hall generators, tunnel diode oscillators, fluxgate sensors and magnetoresistive sensors. The results in terms of detection range for the magnetic field strength and the detectable frequency range are presented in Fig. 3.

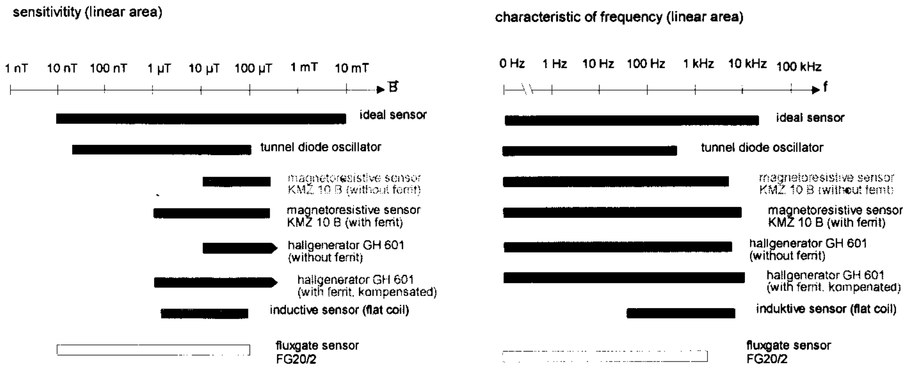


Fig. 3: Comparison of different sensor types, the linear range of their sensitivity and the detectable frequency range

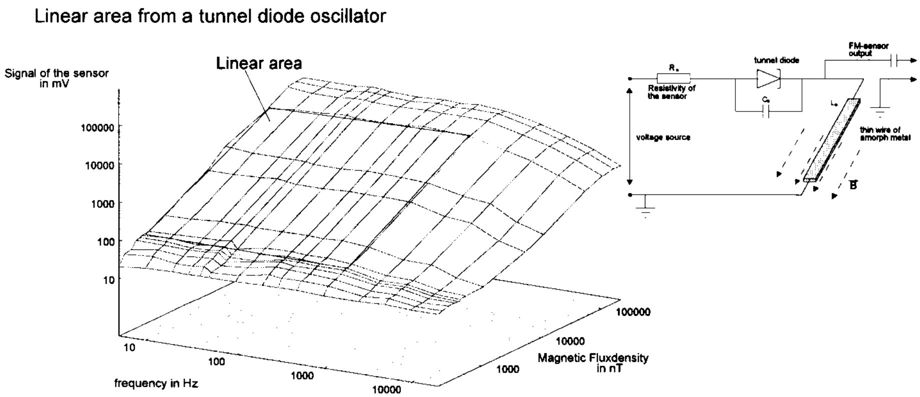


Fig. 4: Linear range from a tunnel diode oscillator

For radiation protection purposes an ideal sensor should cover the sensitivity rage from 10 nT up to at least 10 mT and the frequency rage from DC up to 30 kHz. Compared to that conditions, none of the tested sensors covers all. In consequence a combination of different sensor types will be necessary. Such a combination could be a fluxgate sensor combined with a coil. The mentioned coil has to cover the „upper“ frequency range. An example for the linear range of the sensor signal of a tunnel diode oscillator over frequency and the magnetic field is presented in Fig. 4. Also for magnetic field sensors the choice, which is best, depends strongly on the application.

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