ELECTRO MAGNETIC POLLUTION AND ITS MITIGATION

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The primary concern with any source of electricity is the fact that electromagnetic fields are naturally emitted as a consequence of the transmission, distribution and use of electricity. While the electric fields are relatively easy to block, the magnetic fields are difficult to block and can cause some problems including human biological effect. Since electromagnetic field is present wherever electricity is used, there is a level of EMF in any building due to multiple sources of electromagnetic fields. These sources include the structure's electrical distribution systems, lights, transformers, electric fans, copiers, underground wires, ground-mounted transformers, common sources within the home and work places etc. Also the nearby high voltage power lines are considered one of the EMF sources. This makes the ambient level of indoor electromagnetic pollution exceeds the tolerable limits.

To reduce indoor electromagnetic pollution, different electromagnetic fields mitigation methods could be used. Different mitigation methods are summarized in this paper. The cancellation method by using the correct indoor electrical wiring is discussed in this paper. The using of metal tubes as wall conduits for wires is considered, in this paper, a way of electromagnetic fields mitigation. The effect of material shielding on the indoor electromagnetic pollution is discussed also in this paper.

INTRODUCTION

Everyone is exposed to a complex mix of electromagnetic fields (EMFs) of different frequencies that permeate our environment. Exposures to many EMFs frequencies are increasing significantly as technology advances unabated and new applications are found. While the enormous benefits of using electricity in everyday life and health care are unquestioned, during the past 20 years the general public has become increasingly concerned about potential adverse health effects of exposure to electric and magnetic fields at power frequencies of 50 Hz that are known as extremely low frequencies (ELF) [1]. Such exposures arise mainly from the transmission, distribution and use of electrical energy. Electric and magnetic fields are a basic force of nature generated by electricity from both natural and human made sources. Exposure to EMFs comes from nearby high voltage transmission lines, nearby distribution lines, indoor wirings and electric appliances. Common objects such as trees, fences, and walls easily shield electric fields (EFs). Magnetic fields (MFs) are difficult to shield; this is why MFs produced by power lines can extend into nearby people's homes [1, 2].

In large buildings where flats, offices, education places and work areas are located near electrical systems such as transformers, network protectors, secondary feeders, switchgears, bus bars, and electrical panels, the occupants are usually exposed to very high 50 Hz magnetic field levels. Occupants are not aware of this potential hazard unless the magnetic source produces electromagnetic interference (EMI) in sensitive electronic equipment such as monitors, computers, magnetic media, audio/video equipment, etc. Once detected, 50 Hz magnetic field mitigation ultimately becomes the responsibility of the building management; otherwise the occupants may seek legal action. When electromagnetic field levels are elevated, the ELF magnetic field mitigation is considered as an option to reduce exposure and potential EMF problems. Elevated electromagnetic fields are produced by various sources such as transmission and high current distribution lines, substations, transformers, secondary feeders, switchgears, bus bars, electrical panels, grounding systems, plumbing currents,

wiring loops and sub panel feeders, office equipment, Laboratory devices, shop tools, and machinery. Magnetic field mitigation begins with an ELF EMF contour survey of the site that includes a detailed assessment of the electrical sources and the resultant magnetic field characteristics including magnitude, polarization, harmonic content, temporal and spatial variations [5, 6].

In this paper, the author presents some measured results concerning different techniques for electromagnetic fields mitigation.

SOURCES OF EM POLLUTION

We are exposed to EMFs from many sources [1-4], including nearby high voltage transmission lines carrying electricity from generating plants to communities, and distribution lines that bring electricity to homes, schools and workplaces. We are also exposed to magnetic fields from electrical wiring in buildings and from all our electric appliances like TV sets, radios, hair dryers, electric blankets and electric tools [3]. EFs are present whenever voltage exists on a wire, and are not dependent on current. The magnitude of the electric field is primarily a function of the configuration and operating voltage of the line and decreases with the distance from the source. The EF can be reduced by shielding with any conducting surface, such as trees, fences, walls, buildings, and most types of structures. The strength of an electric field is measured in volts per meter (V/m). MFs are present whenever current flows in a conductor, and are not dependent on the voltage on the conductor. The strength of these fields also decreases with distance from the source [5]. However, unlike EFs, most common materials have little shielding effect on magnetic fields. The MFs strength is a function of both the current on the conductor and the design of the system. MFs are measured in units called Gauss. However, for the low levels normally encountered near power systems, the field strength is expressed in a much smaller unit, the milligauss (mG). Power frequency EMFs is present where electricity is used. This includes not only utility transmission lines, distribution lines, and substations, but also the electrical wiring in homes, offices, and schools, and in the appliances and machinery used in these locations. MF strengths diminish with distance. Fields from compact sources, those containing coils such as small appliances and transformers, decrease in inverse proportional to the distance from the source cubed. For three-phase power lines with balanced currents, the magnetic field strength drops off inversely proportional to the distance from the line squared. Fields from unbalanced currents, which flow in paths such as neutral or ground conductors, fall off inversely proportional to the distance from the source. Conductor spacing and configuration also affect the rate at which the magnetic field strength decreases [8]. The strongest magnetic fields around the outside of a substation come from the power lines entering and leaving the station. The strength of the magnetic fields from transformers and other equipment decreases quickly with distance. Beyond the substation fence, the magnetic fields produced by the equipment within the station are typically indistinguishable from background levels.

EMF EFFECTS

Research on the health effects of EMF has been carried out since the 1970s. Epidemiological studies have mixed results. Some have shown no statistically significant association between exposure to EMF and health effects, and some have shown a weak association. More recently, laboratory studies have failed to show such an association, or to establish a biological mechanism for how magnetic fields may cause cancer. Most concluded that there is insufficient evidence to prove an association between EMF and health effects; however, many of them also concluded that there is insufficient evidence to prove that EMF exposure is safe [1-10].

EMF MITIGATION

Field mitigation minimizes the impact that MFs have on their surroundings. It may be necessary to reduce MFs interference or to allay public or employee concern. Electric and magnetic field exposures in individual residences can be attributed to fields from adjacent power lines, fields from electrical wirings in the home, fields from the operation of electrical appliances, or a combination of all three. In

most cases the fields originating from within the house are not the subjects of public regulation. Electric utilities have a variety of methods for reducing EMF exposures when they upgrade or install transmission and distribution lines. The main methods for mitigating EMF include increasing distance from the line, using phase cancellation, shielding, and limiting voltage and current flow levels [1-10].

The amount of EMF exposure is related to the distance from a power line source. The strength of both the electric and magnetic fields from traditional overhead transmission lines is inversely proportional to the square of the distance from the source. Therefore the level of exposure decreases rapidly with increasing distance from the source conductors. Utilities primary methods of increasing distance include increasing the conductor height above ground, increasing the width of the right of way, or relocating the line to a route more distant from inhabited areas[8-10].

Lines with current-carrying conductors positioned vertically on power line structures produce lower magnetic fields than power lines with conductors positioned horizontally. A common transmission line configuration is the vertical double-circuit, where a set of three conductors is attached, one above the other, to each side of the transmission tower. The three conductors comprise the three phases of the power network, with each conductor carrying current. Electric utilities use the letters A, B and C to denote a three-phase circuit, with each letter representing one conductor and its phase. A little extra cost, electromagnetic fields can be reduced by 50 percent or more by reversing the phase order of the circuit (i.e., C, B and A). Partial cancellation of both magnetic and electric fields is thus achieved. The effectiveness of this arrangement is also dependent on the current flowing through each circuit. Another less used approach is to generate out-of-phase fields from a separate conductor placed between the transmission line and the area where field reduction is desirable. Fields equal to and opposite in magnitude from those emitted by the power line would be generated to cancel the fields from the power line. This approach is not very practical except for specific locations[8-10].

The electric field component of EMF is easily shielded by most structures. However, the magnetic fields are difficult to contain with shielding. Some materials exist that have magnetic shielding characteristics, but the expense of these items is such that the application is mostly limited to small projects and specific locations. Most frequently the affected device is a computer monitor that is exhibiting jitter or color distortion. External magnetic fields impinge upon the monitor's internal magnetic fields and disrupt the electron beam as it writes to the screen. Monitor shields; such as the FMS jitter box create a path for the magnetic fields around the monitor rather than through it, thus enabling the electron beam to perform uninterrupted. In those instances where monitor shielding is not an acceptable option, either the magnetic field source or the affected area can be shielded. Frequently a transformer vault or the electric service panel can be shielded least expensively as part of a building power upgrade or renovation plan. Post renovation, it is more common that the affected area requires shielding due to space and access restrictions. Traditional methods of shielding rely on a method called Flux Shunting or "Big Iron" where the fields are deflected. The two drawbacks to this method are that it frequently creates new problems in adjacent areas and the materials used are thick and exceptionally heavy[5-7].

The principles for mitigating EMF for primary distribution lines are identical to that noted above for transmission lines, including increasing distance, phase cancellation, and underground. Primary distribution right-of-way is normally much narrower than transmission right-of-way, usually 3-5 m wide compared to 15-50 m for transmission right-of-way. The National Electric Safety Code dictates minimum clearances of distribution lines to other facilities. These easements are normally located along streets or rear lot lines and alleys adjacent to the homes and businesses obtaining service. Because of the narrow right of way and the lower clearance, homes and businesses are closer to the distribution line and thus are likely to experience higher magnetic fields. The size of the magnetic field from a distribution line depends on the amount of current flowing on that line, which again is dependent on the use of electricity. Generally current flows on primary distribution lines are lower than on transmission lines, thus creating lower magnetic field levels. With the lower voltages of distribution power lines, conductors can be located much closer together. This allows greater magnetic field cancellation between phase wires of a three-phase line[8-10].

SAFE LIMITS OF EM POLLUTION

The strength of magnetic fields varies depending on many different factors, including the magnitude of the current and the proximity to an EMF source. Because magnetic fields decrease with distance from the source, the magnitude of the magnetic field is higher in homes near a power line than those further away. Similarly, values near appliances or interior electrical wiring may be higher than an average mid-room reading. Because most materials shield the electric field the typical electric field in a house does not exceed 100 V/m. In a study conducted by the Electrical Power Research Institute [11], spot measurements in 992 homes throughout the U.S. showed that half (50%) of them had magnetic field measurements of 0.6 mG or less, when the average of measurements from all the rooms in the home was calculated. These measurements primarily reflect the fields from internal household wiring, electrical grounding sources, and power lines. Exposures in occupational settings (e.g., working on a computer or operating a machine/tool) are typically much higher than residential settings. In 1998 a nationwide random survey of 1000 individuals was conducted to measure 24-hour time-weighted average exposures to magnetic fields [9-10]. The geometric mean for this survey was 0.9 mG. Approximately 15% of the population was estimated to have exposures exceeding 2 mG; 2.4% had exposures exceeding 5 mG, and 0.4% had exposures exceeding 10 mG. The last value indicates that about 1 million people in the U.S. have an average 24-hour exposure greater than 10 mG. Peak exposures at a single point in time are often considerably higher due to people's exposures to appliances, wiring, and other sources. About 0.5% of the population had an estimated maximum exposure to magnetic fields of 1000 mG. Overall, commercial and residential power distribution systems can be a more significant source of magnetic field exposure than transmission lines, but they are usually not a very significant source of large electric fields [9-10].

2.5 mG is the generally accepted limit of ELF magnetic field pollution but no one tells you that the average hair dryer, vacuum cleaner, or can opener you use emits about 300 mG or more. After more than 25 years of intensive study, the health and safety conscious Swedish government has established a safety limit for exposure to ELF magnetic field at 2.5 mG, and VLF magnetic fields at only 0.25 mG. Although the U.S. government has been slower to act in establishing its own standards, the Swedish standard is generally accepted throughout the world [12,13]. What this possibly means is that if someone consistently experiences exposure, which exceeds the standard, that person could be at risk for developing health problems which can range from headaches, fatigue, and dizziness to skin rashes, miscarriage, leukemia, and cancer.

TEST SYSTEM OF EM POLLUTION

To test any place like homes, education places, streets, public places,…etc. for EM pollution, the values of magnetic field must be measured and tested against the safe values. This can be done by walking through the region with an ELF/EMF meter. If the reading is generally below 1.0 mG except near appliances, the region is wired correctly and the degree of EM pollution in such region is accepted. If there is an extensive of higher readings, you need to determine if the EM is coming from a source of EM pollution outside and / or inside such region. To start, walk outside the tested region and see what the readings are around it. Then turn off all the expected sources of EM pollution and also the sources of electricity and check inside the tested region. The result will tell you if need to go further and check the electrical wirings in such region [9-10] .

Concerning the electromagnetic field mitigation, Fig. 1 shows a laboratory simulation of electrical wiring. This system consists of electrical wires, plastic and metallic conduits, autotransformer, load, clamp ammeter, voltmeter, field meter, electric supply and shielding cabinet. The wires are installed inside conduits and feed the load as shown in Fig. 1. The magnetic field density B in mG is measured, as an indication to the electromagnetic pollution, by using field meter [1] while the loading current

and terminal voltage are measured by using clamp meter and voltmeter respectively. The shielding cabinet consists of five sides and is constructed from black iron sheets with 2 mm thickness.

RESULTS AND DISCUSSIONS

The change in the degree of EM pollution due to mitigation can be calculated from the measured values in certain regions from the relation; (unmitigated value – mitigated value)/(unmitigated value).

Figures 2 and 3 show the effect of the type of conduit materials on the values of the magnetic field density. It is seen that using metallic conduits instead of plastic ones in electrical wirings, Figs. 2 and 3 decreases the magnetic field density and then the degree of EM pollution. These lead us to use metallic conduits in electrical wirings in buildings to mitigate electromagnetic fields emanating from them. By using iron tubes, the electromagnetic pollution in such region is mitigated by about 40%, Fig. 4. There is no effect on magnetic field due to earthing the metallic tubes as shown in Fig. 5. Also there is no effect on measured values due to using double tube as electrical conduits, Fig. 6.

Increasing the spacing distance between the EMF source and the object as shown in Fig. 7 mitigates the electromagnetic pollution. The electromagnetic fields are mitigated by about 85% by increasing the distance by one meter from the loaded electrical wirings, Fig. 7.

Figures 8 and 9 show the effect of using object shielding cabinet on the measured values of magnetic field density emanating from electrical wiring and autotransformer respectively. By using black sheets shielding cabinet with five sides, the electromagnetic fields are mitigated by about 30% for electrical wiring system, Fig. 8 and by about 68% for fields emanating from autotransformer, Fig. 9. The electromagnetic Fields also are mitigated by unloading the transformers, Fig. 10. This means that the degree of EM pollution is decreased by decreasing the transformer loading.

Figure 11 shows the electromagnetic field density versus loading current for single and twin wires. The electromagnetic fields emanating from electrical wirings, are mitigated by about 93 %, Fig. 11 by instillation both hot and neutral wires adjacent each other in the same conduit.

CONCLUSIONS

On the bases of the mitigation electromagnetic pollution in buildings, the following conclusions could be drawn:

- **The decreasing of the loading current mitigates the electromagnetic pollution degree especially during the night time.**
- **The increasing of the distance between the electromagnetic field source and the life area mitigates the degree of electromagnetic pollution.**
- **The using of insulated wires adjacent each other, with correct electrical wiring, mitigates the indoor electromagnetic pollution due to electromagnetic fields cancellation phenomena.**
- **The using of shielding cabinet mitigates the electromagnetic fields and improves the degree of electromagnetic pollution.**
- **The installation of metallic tubes as electrical conduits in indoor wirings mitigates the electromagnetic fields and improves the degree of EMFs pollution.**

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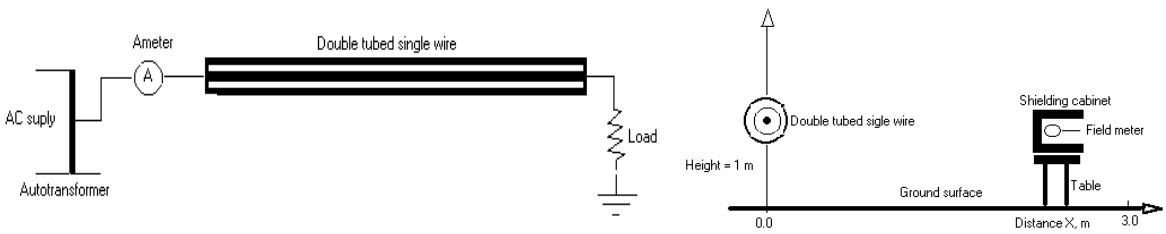

Fig. 1: Test arrangement (A) (left side): Electrical conduit. (B) (Right) Shielding cabinet.

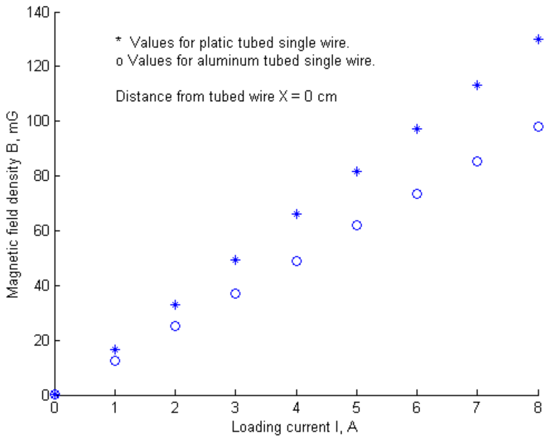

Fig. 2:MF **versus current for plastic and aluminum** conduits.

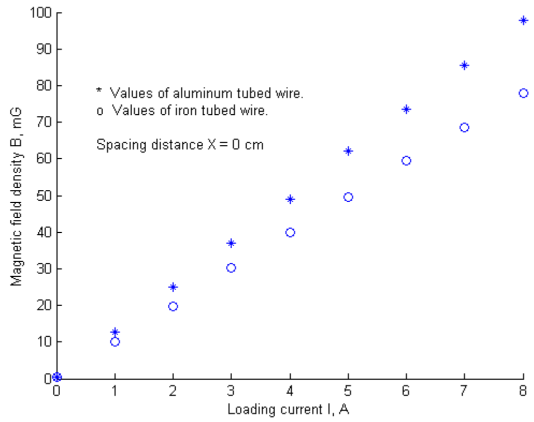

Fig. 3: MF versus I for aluminum and iron conduits.

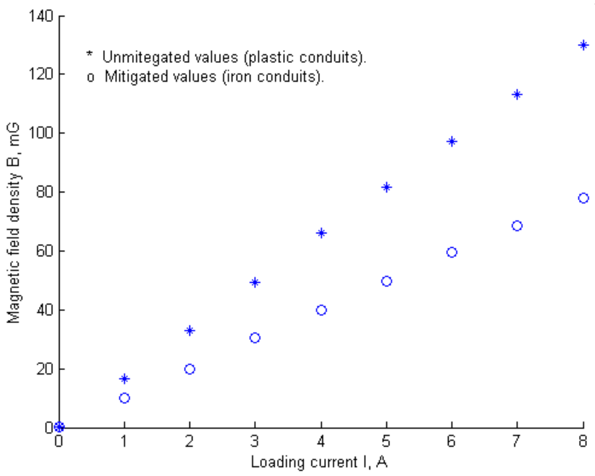

Fig. 4: EMF mitigation due to material conduits.

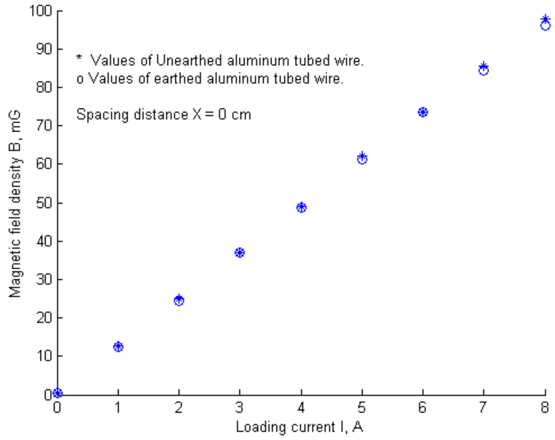

Fig. 5: MF versus I for earthed and unearthed conduits.

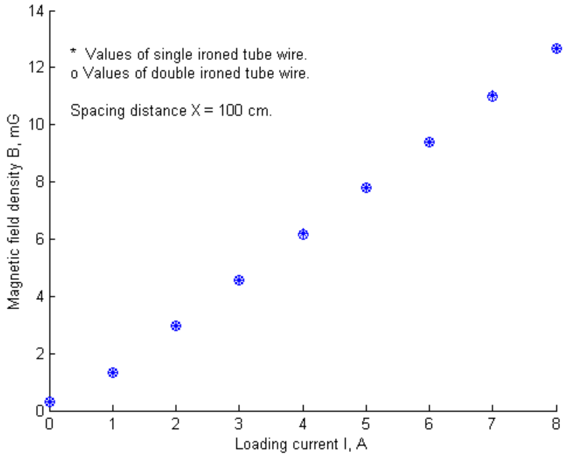

Fig. 6: MF versus I for single and double conduits.

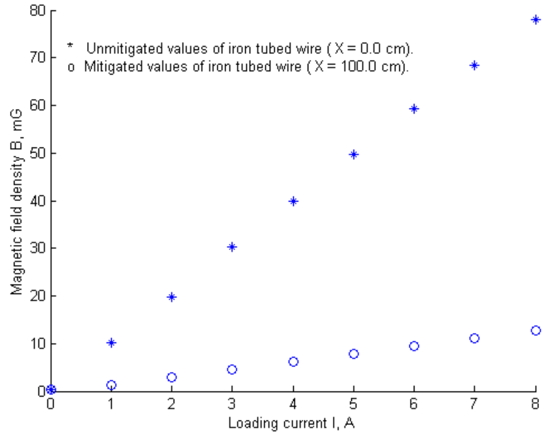

Fig. 7: EMF mitigation due to source spacing.

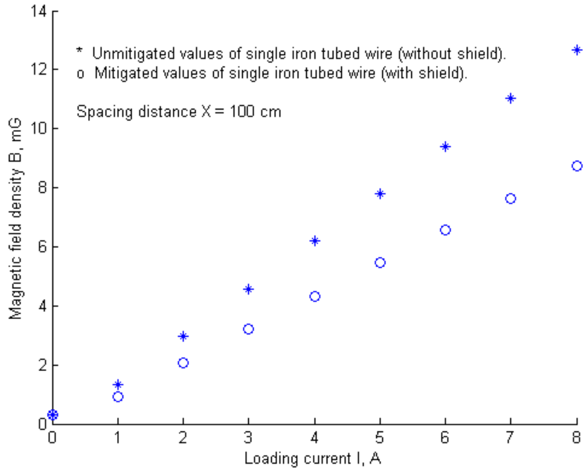

Fig. 8**:** EMF mitigation due to shielding.

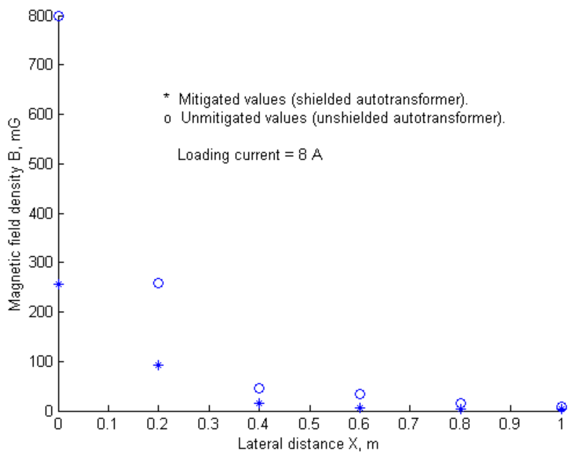

Fig. 9**:** EMF mitigation due to autotransformer shielding.

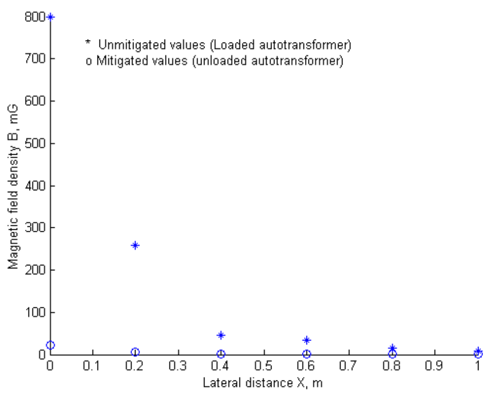

Fig. 10: EMF mitigation due to unloading autotransformer.

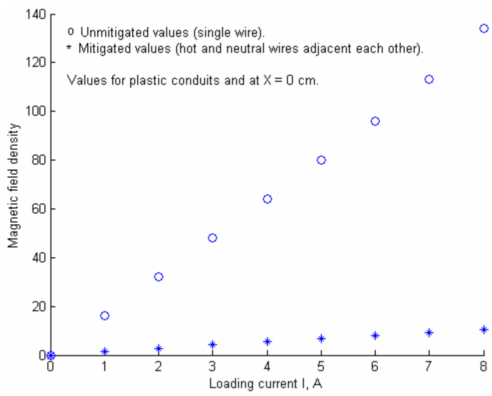

Fig. 11: EMF mitigation due to neighboring wires.

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التلوث الكهرومغناطيسي وتلطيفه

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الطائف ـ المملكة العربية السعودية

لقد اعتبر كثير من الباحثين أن التعرض للمجالات الكهرومغناطيسية ذات القيم التي تتعدي القيم المسموح بها أو التعرض لتلك المجالات لزمن أطول نسبيا يؤدي إلي الإصابة ببعض الأمراض التي قد تصل إلي الأمراض السرطانية. ومن ناحية أخري فانه قد زاد استخدام الأجهزة المنزلية الكهربائية إلي الحد الذي قد يسبب زيادة درجة التلوث الكهرومغناطيسي داخل المباني. كل هذا دفع إلي الاهتمام بدراسة التلوث الكهرومغناطيسي بالمباني والعمل علي تلطيفه أي إتباع الطرق المناسبة لتقليل درجة ذلك التلوث. ففي هذا البحث تم مناقشة بعض الطرق التي تستخدم في تلطيف المجالات الكهرومغناطيسية داخل المباني. كما تم إجراء بعض القياسات المعملية لقيم المجالات الكهرومغناطيسية لتدعيم هذه المناقشة. ومن الطرق التي تطرق إليها هذا البحث لتلطيف المجالات الكهرومغناطيسية وتحسين درجة التلوث داخل المباني زيادة البعد عن مصدر المجالات وتقليل تيار الحمل واستخدام المواسير المعدنية بدلا من المواسير البلاستيكية في التوصيلات الكهربائية بالمباني ووضع كل من السلك الحي وسلك التعادل متجاوران في مجري واحدة واستخدام الحاجب الكهرومغناطيسي المصنوع من ألواح الحديد الأسود.