



The Effects of Non-Ionizing Electromagnetic Field from Federal University Birnin Kebbi Office Appliances on Human Health

Abdullahi Bako^{1*}, Ananwude Ekene Kelvin², Mansur Kabir³, Mahmud Farouk Rugga⁴, Auwal Mustapha Imam⁵

^{1,2,4}Department of Physics with Electronics, Faculty of Science, Federal University, Birnin Kebbi, Kebbi State, Nigeria.

³Advance Aircraft Engineering Laboratory, Gusau. National Space Research and Development Agency (NARSDA).

⁵Air Force Institute of Technology (AFIT), Kaduna.

Abstract

The effects of non-ionizing electromagnetic exposure on human health have become the focus of interest for many years due to its potential health hazards. Several electrical appliances, such as the fridge, laptops, electric bulb, radio, television, microwave oven, ceiling fans, and mobile phone, are inevitably involved with events in our lives, and they all generate electromagnetic radiation. In order to explain the previous studies of electromagnetic radiation effects on the human body, this study focuses on the effects of non-ionizing electromagnetic radiation from FUBK office appliances on human health. This study adopts an analytical design that involves field measurements. The population of this study comprises five (5) department offices in FUBK, where common office appliances, such as laptops, air conditioners, electric bulbs, ceiling fans, and fridges are used. The study focuses on five offices, each subdivided into two segments, resulting in a total of ten segments. Dosimeter Tester Counter meter was used to collect data on the levels of non-ionizing electromagnetic radiation emitted by office appliances, and also for measuring the threshold values for both electric field (EF) and magnetic field (MF). Data will be collected based on Magnetic Field (MF) and Electric Field (EF) through direct measurement, and radiation readings were recorded at regular intervals covering various distances of 0m, 1m, 2m, and 3m. The mean for each appliance was taken as the average of the measurements per distance. For the magnetic field (MF), the fridge emits more radiation, and for the electric field (EF), the ceiling fan emits more radiation. The experiment is helpful as a preventive health measure for students and staff of FUBK.

Keywords: Effect, Non-Ionizing Radiation, Electric Field, Magnetic Field, Human Health, Office Appliances, Dosimeter Counter.

INTRODUCTION

In the contemporary world, the use of electronic devices and office appliances has revolutionized both our personal lives and work environments. These appliances, including laptops, computers, printers, air conditioners, mobile phones, ceiling fans, electric bulbs, and Wi-Fi routers, have become indispensable tools for productivity and connectivity in educational institutions such as the Federal University of Birnin Kebbi (FUBK). However, this proliferation of technology has raised concerns about the potential health effects of non-ionizing electromagnetic radiation emitted by these devices within office spaces [1].

Radiation exists in two main forms: Electromagnetic (EM) radiation, which consists of alternating electric and magnetic waves that propagate energy, and particle radiation, which includes accelerated particles like electrons and protons. EM radiation can be broadly categorized into non-ionizing and ionizing types. Both forms can be encountered clinically

or environmentally, and exposure can have either positive or negative effects on tissues and organisms. For instance, non-ionizing radiation exposure, such as skin exposure to ultraviolet radiation (UVR), can be beneficial for vitamin D production but may also lead to negative effects like photoaging and photo-carcinogenesis [3-8].

Electromagnetic radiation is a fundamental force of nature, characterized by the propagation of energy in the form of waves or particles. It spans a vast spectrum of wavelengths, from extremely low-frequency (ELF) radiation to radiofrequency (RF) radiation and beyond, according to the World Health Organization in 2019. At one end of this spectrum are ionizing radiation such as X-rays and gamma rays, which carry sufficient energy to ionize atoms or molecules, potentially causing cellular damage and DNA. However, at the other end are non-ionizing radiations, where the energy per photon is insufficient for ionization to occur, and non-ionizing radiation encompasses the radiation emitted by common office appliances and electronic devices,

Citation: Abdullahi Bako, Ananwude Ekene Kelvin, et al., "The Effects of Non-Ionizing Electromagnetic Field from Federal University Birnin Kebbi Office Appliances on Human Health", Universal Library of Physics, 2026; 1(1): 35-42. DOI: <https://doi.org/10.70315/uloap.ulphy.2026.0101008>.

according to the Federal Communications Commission in 2017. Electromagnetic hypersensitivity, or EHS, is operationally defined as the self-reported experience of symptoms such as headaches, fatigue, sleep disturbances, skin irritation, and other health issues that individuals attribute to exposure to non-ionizing electromagnetic radiation from office appliances [4-12]. On the health issues related to non-ionizing electromagnetic radiation, non-ionizing electromagnetic radiation has been shown to enhance the cellular production of free radicals, impair the integrity of the blood-brain barrier, and diminish cognitive functions. These effects can lead to genotoxic damage, an increased risk of cancer, reduced male fertility, heightened allergic and hypersensitivity reactions, and the onset of diabetes mellitus [7-9]. The following health outcomes may arise:

1. **Electromagnetic Hypersensitivity (EHS):** A major concern regarding exposure to non-ionizing electromagnetic radiation (NIER) is the phenomenon known as electromagnetic hypersensitivity (EHS). This condition is marked by a variety of non-specific symptoms such as headaches, fatigue, disturbances in sleep, skin rashes, and cognitive difficulties. Although some health organizations recognize EHS, the research surrounding its underlying causes and mechanisms is still not definitive [2, 6].

2. **Cancer Risk:** Another significant area of concern is the potential association between NIER exposure and the risk of cancer. Various studies have examined whether long-term exposure to NIER from devices such as mobile phones, laptops, or Wi-Fi routers could elevate the risk of developing specific cancers, particularly brain cancer [3-15]. The findings, however, have been inconsistent, with some research indicating a possible correlation while others report no significant risk.

3. **Reproductive and Developmental Effects:** Additionally, investigations have been conducted regarding the effects of NIER exposure on reproductive health and developmental processes. Some studies have raised concerns about the implications of extended NIER exposure on these aspects [10-20].

Health Outcomes: Health outcomes in this study encompass any physical or psychological conditions, symptoms, or discomfort reported by FUBK staff and faculty members that they associate with their exposure to non-ionizing electromagnetic radiation. These may include EHS symptoms, as well as any other health concerns communicated by the participants. These appliances include laptops, computers, printers, air conditioners, mobile phones, photocopiers, ceiling fans, electric bulbs, and Wi-Fi routers

Evidence-Based Recommendations: Evidence-based recommendations refer to actionable and well-informed suggestions and guidelines derived from the research findings.

Academic and administrative offices in the context of this study pertain to the designated spaces within FUBK's

campus where faculty members, administrative staff, and other employees conduct their work-related activities. These spaces include individual offices, shared workspaces, meeting rooms, and other areas where office appliances are commonly used.

The widespread use of electronic devices and office appliances (i.e., fans, LED bulbs, laptop systems, refrigerators, e.t.c) within FUBK offices has given rise to significant concerns regarding their potential impact on the health and well-being of staff, faculty, and students. Despite the convenience and efficiency these devices have to offer, several critical issues, like the exposure to non-ionizing radiation, remain unaddressed in settings such as Federal University Birnin Kebbi offices. And there is a scarcity of empirical data specific to FUBK offices to substantiate or refute these concerns. Considering these pressing issues, this project aims to conduct a comprehensive study into the effects of non-ionizing electromagnetic radiation from FUBK office appliances on human health.

Health Implications: While NIER emitted by office appliances is generally considered to be within regulatory limits established by organizations such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Federal Communications Commission (FCC), concerns persist regarding potential health implications of prolonged exposure. Studies investigating the cumulative effects of NIER exposure, especially in occupational settings, continue to be of interest. Understanding the levels of non-ionizing electromagnetic radiation emitted by commonly used office appliances within FUBK offices is essential for promoting a safe and healthy work environment.

Exposure Levels and Standards: Several international organizations and regulatory bodies, such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Federal Communications Commission (FCC), have established guidelines and safety limits for NIER exposure. These standards are based on extensive research and are designed to protect individuals from potential adverse health effects associated with NIER exposure.

Health Risk Assessment: By assessing NIER exposure levels, health outcomes, and office appliance types, this study aims to provide a comprehensive health risk assessment tailored to FUBK's unique office environment.

This study contributes to the broader body of knowledge by filling gaps in the review literature [1-25] regarding NIER exposure in educational settings and by providing empirical data relevant to occupational health within educational institutions. We investigate and evaluate the potential health implications of non-ionizing electromagnetic radiation emitted by common office appliances, including computers, laptops, photocopiers, printers, air conditioners, mobile phones, and obtain the following objectives, which quantify and analyze the levels of non-ionizing electromagnetic

radiation generated by these office appliances in the offices, also we explore any potential associations or correlations between prolonged exposure to non-ionizing radiation from office appliances and reported health effects among office workers in the environment. However, we contribute valuable insights to inform the development of safety guidelines and best practices for mitigating electromagnetic radiation exposure risks in office environments. To assess whether there is a link between electromagnetic radiation exposure and reported symptoms of electromagnetic hypersensitivity (EHS) among office workers. Lastly, we formulate evidence-based recommendations for FUBK and other educational institutions to mitigate potential health risks associated with office appliances' non-ionizing radiation emissions.

MATERIALS AND METHOD

Three readings were taken at distances of one, two, and three meters after initially positioning the dosimeter at zero meters from the electric appliance.

Study Area

Federal University Birnin Kebbi (FUBK) is located in Northern Nigeria's Northwest region and was established

Table 1. General table for Magnetic field [MF]

Electronic Device	Distances				Radiation type
	0M	1M	2M	3M	
Air conditioner	61.56 Hz	13.23 Hz	4.19 Hz	1.54 Hz	Extremely low frequency ELF
Ceiling fan	26.52 Hz	7.64 Hz	3.06 Hz	1.56 Hz	Extremely low frequency ELF
Electric bulb	13.77 Hz	4.12 Hz	1.54 Hz	0.45 Hz	Extremely low frequency ELF
Laptop	2.66 GHz	2.14 GHz	1.35 GHz	0.57 GHz	Microwave/Radiofrequency
Fridge	65.8 Hz	11.58 Hz	4.66 Hz	2.6 Hz	Extremely low frequency ELF

The results of the magnetic field measurements obtained from various office appliances at different distances are presented in Figures 1–4. These measurements were conducted across two offices within five departments at the Federal University of Birnin Kebbi, using common office appliances including an air conditioner, ceiling fan, electric bulb, laptop, and refrigerator. At 0 m (Figure 1), the refrigerator and air conditioner contributed the largest proportions of the magnetic field, accounting for 39% and 36%, respectively. In contrast, the electric bulb and laptop exhibited minimal contributions (8% and 1%, respectively), while the ceiling fan contributed 16%. This indicates that appliances with higher power consumption and internal electromagnetic components tend to emit stronger magnetic fields in close proximity. At 1 m (Figure 2), the contribution of the air conditioner remained dominant at 34%, followed by the refrigerator at 30%. The ceiling fan contribution increased slightly to 20%, while the electric bulb and laptop remained relatively low at 11% and 5%, respectively. This suggests a gradual attenuation of the magnetic field with distance, although dominant sources still maintain significant influence. At 2 m (Figure 3), a more noticeable reduction in

on the 18th of February, 2013, by the federal government of Nigeria, situated along Kalgo-Bunza road, Kebbi State, Nigeria. The university is located between longitude 4 0915' E and latitude 121955'N, covering a total land area of about 500,000 hectares (5000km²), with a population of more than 3600 individuals, both staff and students. Due to the large population and building infrastructure on the campus, there is a need to determine the level of non-ionizing radiation dose of FUBK

RESULT AND DISCUSSION

The presentation of results in tables according to the analysis of the instruments administered to obtain data for the Electric and magnetic fields radiated from office appliances. All the readings were taken from numerous office appliances and electronic devices from two offices, each in five departments in the Federal University of Birnin Kebbi. Experimental data were collected from the magnetic field and the electric field at various distances in the office. The appliances consisted of a ceiling fan, an electric bulb, a fridge, a laptop, and an air conditioner. The first phase of reading is the Magnetic Field, then the second phase is the Electric Field radiated from these appliances and devices shown in tables 1 & 2

the magnetic field contributions from all appliances was observed. The air conditioner and refrigerator contributed 28% and 32%, respectively, while the ceiling fan accounted for 21%. The electric bulb and laptop remained the least contributors at 10% and 9%, respectively. This demonstrates the expected inverse relationship between magnetic field strength and distance from the source. At 3 m (Figure 4), the distribution became more uniform, with both the air conditioner and ceiling fan contributing equally at 23%, while the refrigerator again showed the highest contribution at 39%. The electric bulb and laptop remained minimal contributors at 7% and 8%, respectively. The persistence of the refrigerator's higher contribution across all distances may be attributed to its continuous operation and internal motor activity. Overall, the results indicate that the magnetic field strength decreases with increasing distance from the source, consistent with electromagnetic field theory. High-power appliances such as refrigerators and air conditioners consistently exhibit higher magnetic field emissions, while low-power devices such as laptops and electric bulbs contribute minimally. These findings highlight the importance of maintaining safe distances from high-emission appliances in office environments to minimize prolonged exposure.

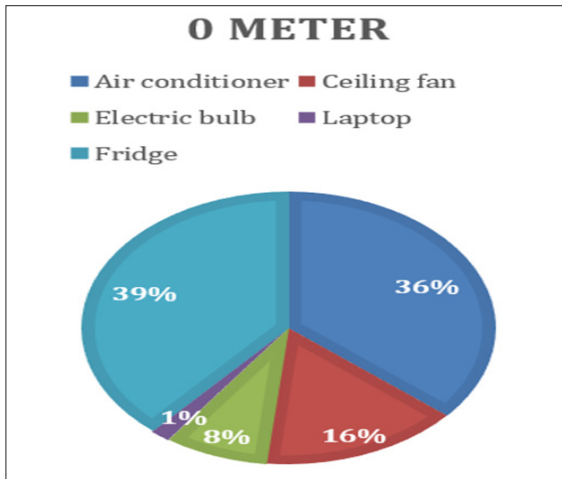


Fig 1. Percentage of the magnetic field at 0 meters

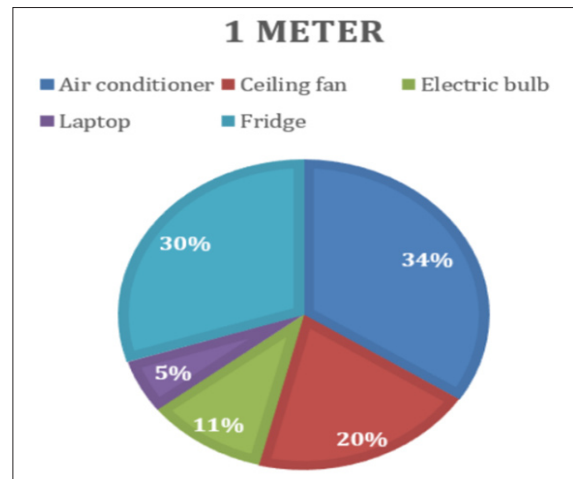


Fig. 2. Percentage of the magnetic field at 1 meter

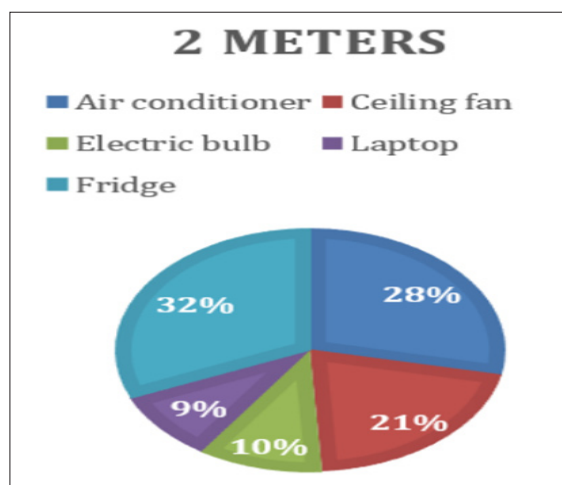


Fig 3. Percentage of the magnetic field at 2 meters

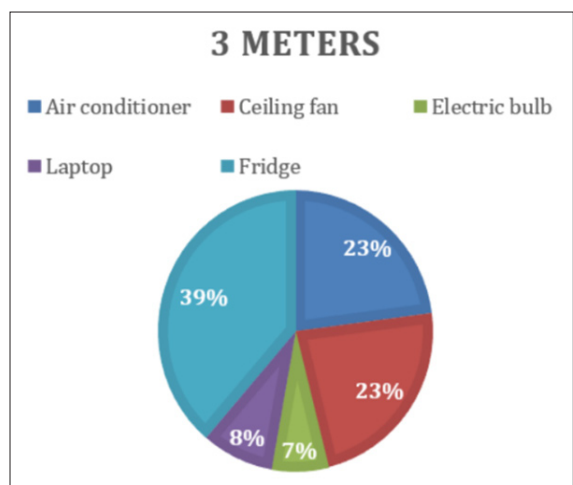


Fig. 4. Percentage of the magnetic field at 3 meters

Figure 5 shows that the magnetic field (MF) intensity is highest at 0 m, particularly for the refrigerator and ceiling fan, while the electric bulb and laptop contribute minimally. As the distance increases from 1 m to 3 m, the MF intensity from all appliances decreases significantly, with values converging at very low levels at 3 m. Overall, the results confirm that magnetic field strength diminishes rapidly with distance, and high-power appliances remain the dominant sources of emission at proximity.

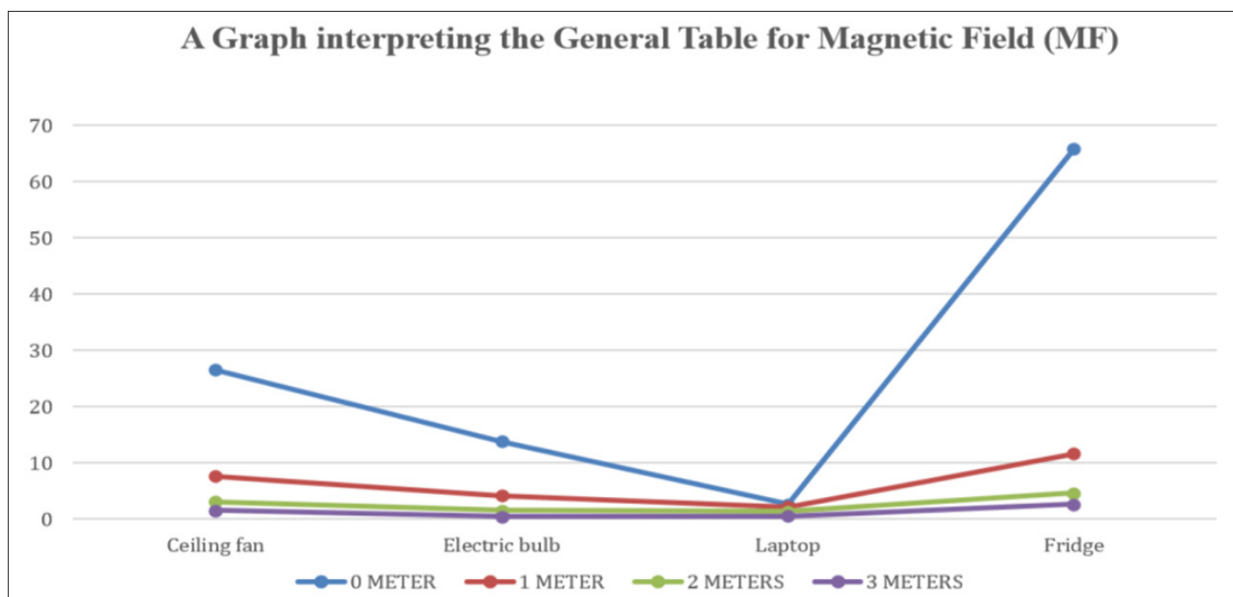


Fig 5. Graph interpreting the general table for the magnetic field (MF)

Table 2. General table for the electric field

Electronic Device	Distances				Radiation type
	0M	1M	2M	3M	
Air conditioner	498.57Hz	220.4Hz	138.4Hz	85 Hz	Extremely low frequency ELF
Ceiling fan	532.92 Hz	310.99 Hz	241.25 Hz	177.51 Hz	Extremely low frequency ELF
Electric bulb	799.69 Hz	242.41 Hz	118.31 Hz	67.77 Hz	Extremely low frequency ELF
Laptop	347.17 GHz	179.2 GHz	173.67 GHZ	133.5 GHz	Microwave/Radiofrequency
Fridge	229 Hz	139.67 Hz	116 Hz	97.Hz	Extremely low frequency ELF

Figures 6–9 illustrate the percentage distribution of the electric field (EF) emitted by office appliances at distances of 0–3 m. At 0 m (Figure 6), the electric bulb and ceiling fan are the dominant contributors, while the refrigerator contributes the least. At 1 m (Figure 7), the ceiling fan becomes the primary source, followed by the electric bulb and laptop, indicating a shift in relative contributions with distance. At 2 m (Figure 8), the ceiling fan remains dominant, while the laptop contribution increases noticeably, and the electric bulb and refrigerator contribute moderately. By 3 m (Figure 9), the ceiling fan still shows the highest contribution, with the laptop becoming the second most significant source, whereas the air conditioner and electric bulb exhibit reduced contributions. Overall, the results indicate that, unlike the magnetic field, the electric field distribution

varies across appliances with distance but does not decrease uniformly. The ceiling fan consistently remains the dominant source of electric field emission, while other devices exhibit fluctuating contributions depending on distance. Figure 10 presents the variation of electric field (EF) intensity (V/m) across different appliances and distances. At 0 m, the electric bulb exhibits the highest electric field intensity, followed by the ceiling fan, while the laptop and refrigerator show comparatively lower values. As the distance increases from 1 m to 3 m, the electric field generally decreases across all appliances, although minor fluctuations are observed, particularly for the laptop. The results indicate that electric field strength reduces with increasing distance, with the electric bulb and ceiling fan being the dominant sources at close range, while all appliances converge toward lower emission levels at greater distances.

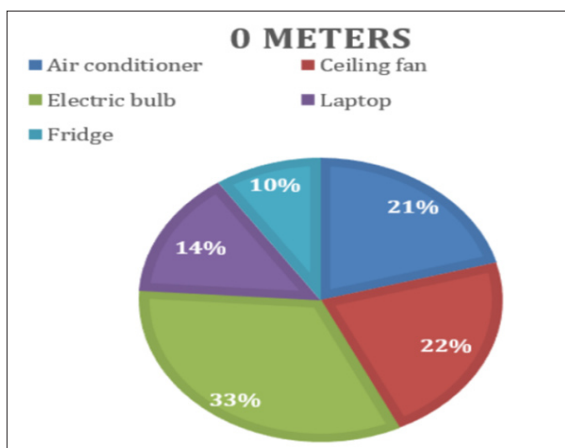


Fig 6. Percentage of the electric field at 0 meters

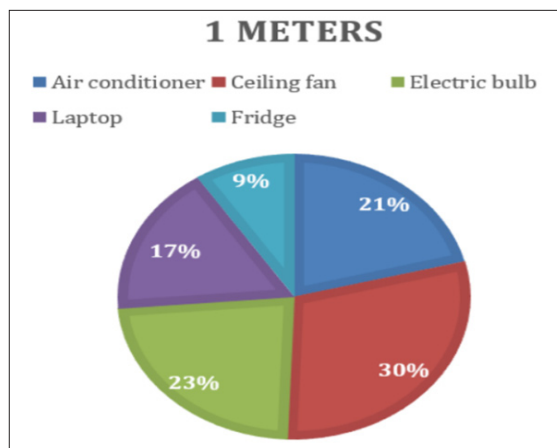


Fig. 7. Percentage of the electric field at 1 meters

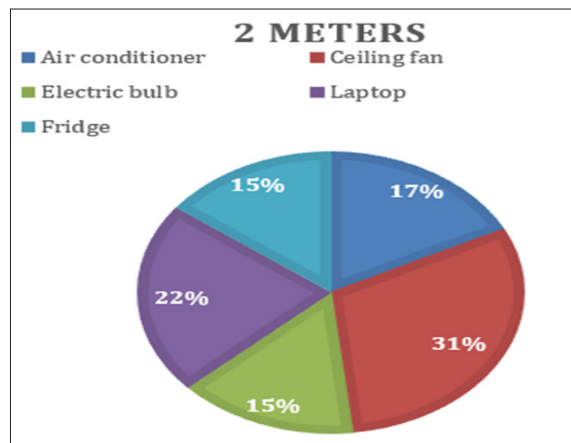


Fig 8. Percentage of the electric field at 2 meters

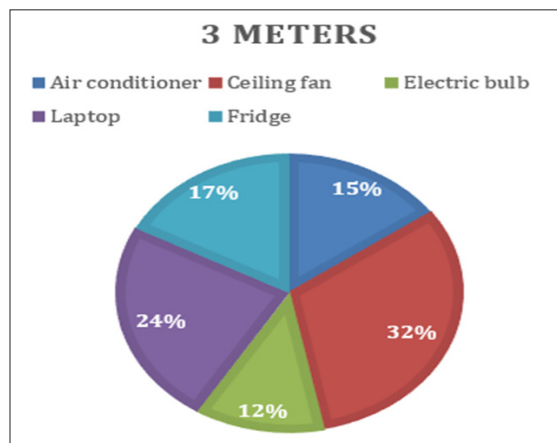


Fig. 9. Percentage of the electric field at 3 meters

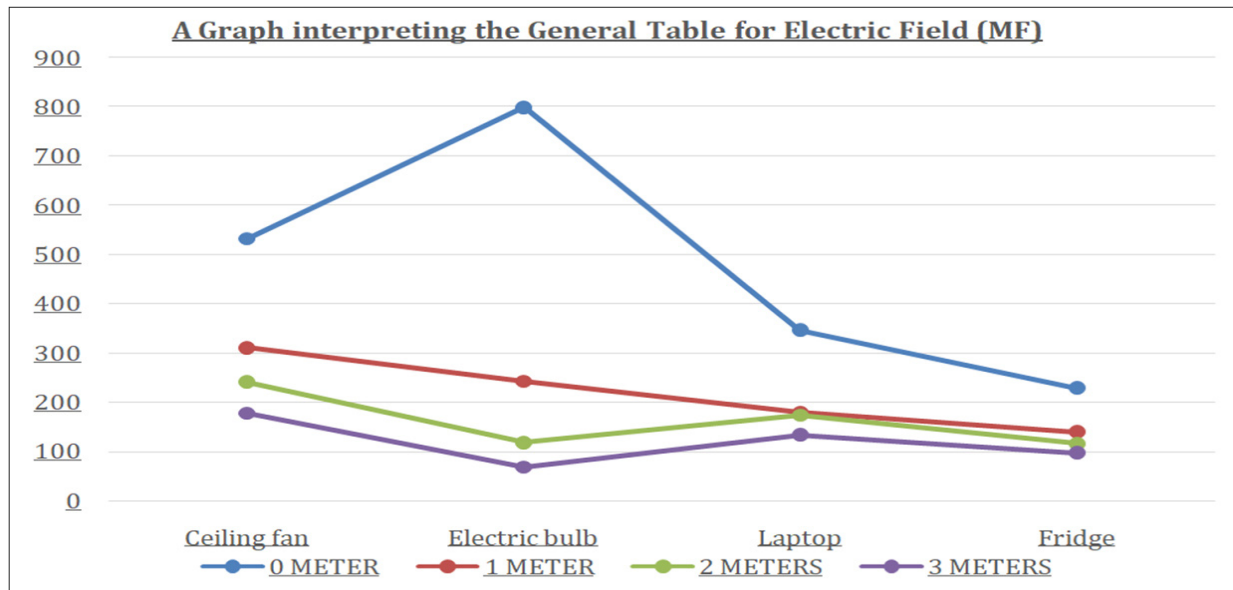


Fig 10. Graph Interpreting the General Table for Electric Field (EF) V/M

Comparing the measured values from the result above for both electric and magnetic field non-ionizing radiation of common appliances with the safety frequency range of non-ionizing radiation using the table below.

Table 3: Safety Range of Non-Ionizing Radiation From Common Appliances

Devices	Frequency Range	Electric field	Magnetic field	Safe	Notes
Wi-Fi router	2.4/ 5 GHz	0.1-1 v/m (at 1-2 m)	<100 μ T (0.1mT)	Yes	Power density more relevant
Smartphone	700MHz – 2.6 GHz	0.5-2 v/m (near device)	<100 μ T (0.1mT)	Yes	SAR limit applies
Laptop	2.4 / 5 GHz	0.05-0.5 v/m	<100 μ T (0.1mT)	Yes	Use on the desk to reduce exposure
TV (LCD/LED)	<100 kHz	<1 v/m	<0.1 μ T	Yes	Minimal emission
Refrigerator	50-60 Hz	<5 v/m	0.1-3 μ T	Yes	Field drops quickly with distance
Air Conditioner	50-60 Hz	10 v/m	0.1-10 μ T	Yes	Avoid prolonged contact
Ceiling Fan	50-60 Hz	< 5 v/m	<0.05-2 μ T	Yes	Low emissions at normal use
Electric Bulb	50-60 Hz	< 1 v/m	<0.1 μ T	Yes	Light can affect sleep

Electromagnetic emissions from common office appliances fall within the non-ionizing, extremely low-frequency (ELF) range and generally remain within internationally accepted safety limits. However, greater concern is associated with continuous exposure to ELF fields from high-voltage transmission lines, which operate at higher intensities and may result in prolonged, low-level exposure for nearby populations. The findings further indicate that electric field levels are comparatively higher than magnetic field values across the studied offices, likely influenced by building wiring configurations. Although the measured levels remain within permissible limits, continuous exposure in occupied environments warrants attention, particularly in settings where individuals may be unaware of potential risks. Reported effects of ELF exposure are varied and nonspecific, including dermatological and neurological symptoms, though these do not constitute a clinically recognized syndrome according to the World Health Organization (2004). While evidence of severe long-term health effects remains inconclusive, precautionary measures such as minimizing prolonged exposure near strong EMF sources, especially high-voltage

transmission lines, are advisable. Additionally, variations in emission levels across appliances and usage conditions suggest that peak operation periods may contribute to increased exposure in office environments. This study reveals significant variations in electromagnetic radiation emissions across different office appliances and usage patterns. Certain devices exhibited higher radiation levels during peak usage times, highlighting potential periods of increased exposure for office occupants.

CONCLUSION

This study evaluated the levels of non-ionizing electromagnetic radiation emitted by common office appliances across selected offices at the Federal University of Birnin Kebbi. Measurements obtained using an electromagnetic radiation detector–dosimeter indicate that radiation levels are highest at close proximity (0–1 m), where both electric and magnetic field intensities show their greatest values.

The results further reveal that, in several instances, the measured magnetic and electric field levels approach or exceed recommended threshold limits for certain appliances.

Although these emissions generally fall within the non-ionizing range, their elevated levels at short distances highlight the importance of exposure awareness in indoor environments.

Overall, the findings emphasize that proximity to electrical appliances is a key factor influencing exposure levels. Consequently, maintaining appropriate distances and adopting precautionary measures can significantly reduce potential health risks for office occupants. This study provides a useful baseline for radiation monitoring and contributes to improving occupational safety for staff and students.

RECOMMENDATIONS

Protective and safety measures against non-ionizing radiation

1. Keeping a safe distance (at least 1.2m) from all electrical appliances in homes and offices.
2. Wear standard laboratory apparel, including a fully buttoned lab coat, long pants, and closed-toe shoes.
3. UV-certified goggles and safety glasses should be put on to protect the eyes
4. Wear disposable nitrile gloves to protect exposed skin to the hands
5. Limit usage: Decrease the frequency and duration of your calls or the time spent on wireless devices.
6. Opt for texting: Texting generates a significantly smaller signal compared to voice calls, leading to reduced exposure to RF energy.
7. Ensure strong reception: Make calls in areas with good reception to minimize RF exposure by avoiding the need for signal boosters.
8. Utilize hands-free technology when possible.
9. Avoiding the use of cordless equipment.
10. Avoid standing right in front or close to antennas.
11. Make sure that the antennas are not pointed directly toward your work area. Stay 6 feet away from a single antenna or 10 feet away from a group of antennas
12. Be cautious not to overheat liquids, as they can reach the boiling point without visible signs and may erupt when disturbed.
13. Avoid using metal stirrers or plastic-coated magnetic stirrer bars, aluminum foil, wires, and cables in the microwave.
14. Do not attempt to heat flammable liquids, hazardous substances, or radioactive materials.
15. Never heat-sealed containers, as pressure can build up and cause an explosion, either in the microwave or shortly after removal.

16. Refrain from using plastic containers that are not microwave-safe.

Awareness should be raised about best practices for reducing exposure, such as maintaining a safe distance from appliances during operation. Guidelines should be developed for the strategic placement of office appliances to minimize exposure to electromagnetic radiation and encourage continuous research to explore the long-term effects of non-ionizing electromagnetic radiation on human health to mitigate potential health risks associated with non-ionizing electromagnetic radiation from office appliances.

REFERENCE

1. Hansson Mild, K., Lundström, R., & Wilén, J. (2019). Non-ionizing radiation in Swedish health care: exposure and safety aspects. *International journal of environmental research and public health*, 16(7), 1186.
2. Birtel, J., Harmening, W. M., Krohne, T. U., Holz, F. G., Issa, P. C., & Herrmann, P. (2017). Retinal injury following laser pointer exposure: a systematic review and case series. *Deutsches Ärzteblatt International*, 114(49), 831.
3. Wojtczak, M., & Piotrowski, Z. (2020, February). Radiation standards review concerning non-ionizing radiation. In *Radio Electronic Systems Conference 2019* (Vol. 11442, pp. 159-168). SPIE.
4. Ekici, B., & Ordahan, B. (2023). Evaluation of the effect of high-intensity laser therapy (HILT) on function, muscle strength, range of motion, pain level, and femoral cartilage thickness in knee osteoarthritis: randomized controlled study. *Lasers in Medical Science*, 38(1), 218.
5. Fehler, N., Lingenfelder, C., Kupferschmid, S., & Hessling, M. (2022). Determination of the intraocular irradiance and potential retinal hazards at various positions in the eye during transscleral equatorial illumination for different applied pressures. *Zeitschrift für Medizinische Physik*.
6. Davis, D., Birnbaum, L., Ben-Ishai, P., Taylor, H., Sears, M., Butler, T., & Scarato, T. (2023). Wireless technologies, non-ionizing electromagnetic fields, and children: Identifying and reducing health risks. *Current Problems in Pediatric and Adolescent Health Care*, 101374.
7. Gupta, S., Sharma, R. S., & Singh, R. (2022). Non-ionizing radiation is a possible carcinogen. *International Journal of Environmental Health Research*, 32(4), 916-940.
8. Jagetia, G. C. (2022). Genotoxic effects of electromagnetic field radiation from mobile phones. *Environmental Research*, 212, 113321.
9. Pall, M. L. (2016). Microwave frequency electromagnetic fields (EMFs) produce widespread neuropsychiatric effects, including depression. *Journal of Chemical Neuroanatomy*, 75, 43-51.

10. Kim, Lee, Yang, Y., Prabhune, O., Chithra, A. L., West, J., Fawaz, K., & Kim, Y. (2022). AEROKEY: Using ambient electromagnetic radiation for secure and usable wireless device authentication. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, 6(1), 1-29.
11. Kivrak, E. G., Gherardi, Yurt, K. K., Kaplan, A. A., Alkan, I., & Altun, G. (2017). Effects of electromagnetic field exposure on the antioxidant defense system. *Journal of microscopy and ultrastructure*, 5(4), 167-176.
12. Mehrotra, P., Chatterjee, B., & Sen, S. (2019). EM-wave biosensors: A review of RF, microwave, mm-wave and optical sensing. *Sensors*, 19(5), 1013.
13. Ravi, S. K., Tan, S. C., Ravi, S. K., & Tan, S. C. (2020). Photoproteins Tapping Solar Energy to PowerSensors. *Solar Energy Harvesting with Photosynthetic Pigment-Protein Complexes*, 127-140.
14. Yashchyshyn Z, Ling, H., Li, Z., Li, K., Zhao, R., Ma, P., Zhou, Y., & Zhang, Y. (2023). Terahertz Electromagnetically Induced Transparency with Electric-Field-Coupled Inductor-Capacitor Resonators on LCP Substrate. *Crystals*, 13(2), 283.
15. Lai, H. (2022). Neurological effects of static and extremely low-frequency electromagnetic
16. Olsztyńska-Janus, S., Kiełbowicz, Z., & Czarnecki, M. A. (2018). ATR-IR study of skin components: Lipids, proteins, and water. Part II: Near infrared radiation effect. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 202, 93-101. *fields. Electromagnetic Biology and Medicine*, 41(2), 201-221.
17. Tsai, S. R., & Hamblin, M. R. (2017). Biological effects and medical applications of infrared radiation. *Journal of Photochemistry and Photobiology B: Biology*, 170, 197-207.
18. Téglás, T., Dörnyei, G., Bretz, K., & Nyakas, C. (2018). Whole-body pulsed EMF stimulation improves cognitive and psychomotor activity in senescent rats. *Behavioural Brain Research*, 349, 163-168.
19. Sinha, D., & Amaratunga, G. (2018). The Noether current in Maxwell's equations and radiation under symmetry breaking. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 376(2134), 20170452.
20. Yamazaki, Nakatani-Enomoto, S., M., Nishiura, K., Enomoto, H., & Ugawa, Y. (2020). Effects of electromagnetic fields from long-term evolution on awake electroencephalogram in healthy humans. *Neuroscience Research*, 156, 102-107.
21. Sideris, S., Akbari, A., Jelodar, G., Nazifi, S., Afsar, T., & Nasiri, K. (2019). Oxidative stress as the underlying biomechanism of detrimental outcomes of ionizing and non-ionizing radiation on human health: antioxidant protective strategies. *Zahedan Journal of Research in Medical Sciences*, 21(4).
22. Zhi, W. J., Wang, L. F., & Hu, X. J. (2017). Recent advances in the effects of microwave radiation on the brain. *Military Medical Research*, 4(1), 1-14.
23. Zhou, F., Ma, C., Li, Y. J., Zhang, M., & Liu, W. (2023). Effect of extremely low-frequency electromagnetic radiation on pregnancy outcome: A meta-analysis. *African Journal of Reproductive Health*, 27(5).
24. Abd-Elsayed, A., Nguyen, S., & Fiala, K., 2019. Radiofrequency Ablation for Treating Headache, *Current pain and headache reports*, 23(3).
25. Baxter, B. L., Seaman, S. J., Arora, C., & Kim, J. H. 2022. Radiofrequency ablation methods for uterine-sparing fibroid treatment. *Current opinion in obstetrics & gynecology*, 34(4), 262-269.