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Original Research Article

Experimental Evaluation of Distance-Dependent User Exposure to Extremely Low-Frequency Magnetic Fields from Computer Devices Under Typical Operating Conditions

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ABSTRACT

Extremely low-frequency (ELF) magnetic fields emitted by information technology equipment have raised public health concerns regarding continued occupational and academic exposure. As computers become essential tools in higher education, enumerating user contact levels is crucial for establishing safety baselines and promoting optimized best practices. This study therefore, evaluated user exposure to extremely low-frequency (ELF) magnetic fields at varying distances from computer devices at the National Open University of Nigeria, Abuja. Ten commonly used desktop and laptop computer models operated continuously for 90–120 minutes prior to measurement. A calibrated GM3120 electromagnetic field meter was used to measure ELF magnetic field strength at distances of 10cm, 20cm, 30cm, 50cm, and 100cm from the front and rear surfaces of the devices. Preliminary measurements indicated the ELF magnetic field measurements from the left and right sides of the devices were insignificant. The experimental results demonstrated that magnetic field strength decreased consistently as the distance from the computer screens increased. For the front screen, radiation values ranged from 0.05 to 2.43 milliGauss (mG) at the closest measurement distance (10 cm), dropping significantly to between 0.01 and 1.04 mG at a 100 cm. Similarly, rear-surface measurements ranged from 0.03 to 0.90 mG at 10cm and decreased to between 0.01 and 0.30 mG at 100cm. Notably, modern laptop models like the Apple MacBook Air M4 and Dell XPS 13 emitted the lowest overall radiation levels. The study concludes that increasing the distance between users and computer devices from both desktop and laptop computer screens significantly minimizes personal exposure to ELF magnetic field exposure.

INTRODUCTION

The rapid advancement of digital knowledge has made computer devices essential in modern daily life, with desktop computers, laptops, and tablets becoming omnipresent in workplaces, schools, and homes to enhance global productivity and connectivity. However, the internal electrical components, power adapters, and circuitry of these computing systems inherently generate extremely low-frequency (ELF) magnetic fields during daily data transmission and power processing operations. Since standard building materials and human skin are fundamentally transparent to magnetic fields, these emissions can penetrate deep biological tissues with minimal attenuation (Kaszuba-Zwoińska *et al.*, 2022). This deep-tissue penetration allows induced internal micro-electric currents to be generated within internal organ systems.

Over long periods, this cellular exposure has ignited a rigorous scientific debate and raised potential public health concerns regarding the long-term biological effects of chronic exposure. Alternating ELF magnetic fields are heavily investigated for their capacity to cause non-thermal cellular stress, changes in cellular signaling, and oxidative stress; while some epidemiologic studies have noted tentative, localized correlations between chronic ambient exposure and adverse cell health developments. However, the broader biological evidence remains complex and highly inconclusive (Correa-Correa *et al.*, 2025). Heterogeneous methodologies and non-standardized endpoints continue to leave the direct clinical significance and exact reproducibility of reported low-frequency biological affects deeply uncertain (Jalilian & Röösli, 2025).

Crucially, spatial distance serves as a primary determinant of user exposure, as the absolute magnetic field strength diminishes rapidly according to the inverse-square law the farther a user moves away from the operational electrical source. Using a computer for long periods negatively impacts human physical and mental health. Prolonged screen exposure reduces natural blinking rates, which directly triggers a cluster of visual symptoms known as digital eye strain (DES) or computer vision syndrome (CVS) (Chowdhury & Kaur, 2025). This ocular fatigue manifests heavily as surface-related symptoms like eye dryness and irritation, alongside accommodation- or vergence-related anomalies that impair binocular system endurance (Zaky *et al.*, 2025). Furthermore, sitting statically for hours with poor ergonomics causes severe posture issues, resulting in chronic neck, shoulder, and spinal pain (Sharma & Gupta, 2025). Beyond physical strain, excessive daily computer use and internet over-engagement alter sleep quality due to melatonin-disrupting blue light, while simultaneously heightening risks for psychological disorders such as anxiety, attention fragmentation, and depression (Hanindhito & Chen, 2026). The resulting screen dependency dictates a strict dose-response relationship, heavily dictating the severity of academic and occupational fatigue experienced by modern users (Jaryal *et al.*, 2025).

Despite established generic environmental guidelines, a significant localized knowledge gap persists regarding real-world, context-specific emission measurements taken from modern, high-efficiency desktop and laptop computers operating under typical, high-load user conditions. Consequently, the primary objective of this study is to measure and quantify the actual ELF magnetic field emission levels from modern computer hardware variants across realistic user distances to verify compliance with international safety standards and ensure long-term public safety.

MATERIALS AND METHODS

Materials

The electromagnetic field meter labeled GM 3120 manufactured in Shenzhen, China is a handheld device used to detect and measure extremely low frequency (ELF) electromagnetic fields between the frequency of 30 to 300Hz and measurement range of approximately 0.01 μT to 20 μT and 1V/M to 1999V/M for magnetic and electric fields. It has a single axis sensor, designed for simple point and use, sampling at approximately 2.5 times per second with user selectable readout in milliGauss (mG) or micro Tesla (μT) through switch. It has a power source of 9v battery with weight of 109g and operating conditions of 0°C to 50°C with up-to-date annual recalibration

Methods

Ten (10) different brands of computers were selected for the study at the National Open University of Nigeria, Abuja. The computers investigated were: DESTOP-OIGPJ7Q, DESTOP-Q4GH51, HP-PROBOOK 450, HP-DLU64QM, LENOVO-SLUS7S, HP-KKKH016, HP-PAVILION DV 6, DELL-PRESARIO F700, APPLE MACBOOK AIR M4, and DELL XPS 13. All devices were verified to be in good working condition and were kept running for at least 90 to 120 minutes prior to data collection to ensure stable operating temperatures and electronic states. To ensure data integrity, measurements were conducted under controlled ambient temperature of 24^0C and baseline ambient electric and magnetic field levels were recorded prior to testing with all target computers powered off to account for background environmental noise.

Device Configuration and Operational States

To standardize the emission profiles of the computers under investigation, all laptops were disconnected from the mains power grid and were connected to standard mains power through their Original Equipment Manufacturer (OEM) charging bricks to capture total operating emissions. Integrated Wi-Fi and Bluetooth modules were explicitly disabled on all devices to isolate extremely low frequency (ELF) emissions from high-frequency radiofrequency (RF) radiation.

Measurement Technique and Positioning Geometry

The GM3120 EMF meter was deployed using a standardized spatial grid to map the ELF radiation attenuation relative to distance. Measurements were taken at precise distances of 10 cm, 20 cm, 30 cm, 50 cm, and 100 cm from both the geometric front (screen center) and back of each computer. The meter's single-axis sensor was oriented perpendicular to the screen and chassis surfaces, aligning the axis of maximum sensitivity directly toward the radiation source. The meter was held in place for 10 seconds per replicate to allow the reading to stabilize, after which the stable instantaneous value was logged. At each specific distance and orientation, three (3) independent repeated measurements were recorded. The final data point used for analysis represented the arithmetic average of the three recorded replicates for each spatial node.

RESULTS AND DISCUSSION

This study investigated Extremely Low Frequency (ELF) radiation levels across ten different computer systems. Specifically, it compared magnetic field emissions from the front and rear surfaces of the devices at set distances ranging from 10 cm to 100 cm.The data reveals a major difference in radiation levels between the front and back surfaces of the computer screens. Across all measurements, emissions from the front face are consistently higher than those taken at identical distances from the back face (Table 1 and Table 2). For instance, at the closest measurement distance (10 cm), the mean magnetic field strength was 1.23 mG at the front surface, compared to just 0.38 mG at the rear surface.

These higher front-surface measurements can be attributed to the active display electronics and internal electrical components located near the screen assembly. Components such as glass substrate layers and inverter circuit boards generate electromagnetic fields directly toward the user (Mild & Mattsson, 2022). Conversely, the back panel of modern monitors often includes internal metallic grounding plates, structural reinforcement brackets, and dedicated electromagnetic interference (EMI) shielding sheets. Therefore, the lower rear measurements reflect these deliberate engineering barriers and differences in internal component layout. A notable exception occurred in an older, legacy system, the HP-KKKH01, which maintained relatively high rear radiation values ranging from 0.88 mG to 0.33 mG across the entire distance spectrum. This observation highlights how much shielding design varies among different computer models and technical generations (Li *et al.*, 2024).

The observed reduction in magnetic field strength as distance increases reflects the classic inverse-square law of electromagnetic field attenuation. This law dictates that field intensity diminishes inversely with the square of the distance from a localized source point, expressed as:

Intensity $\alpha \frac{1}{d^2}$

Notably, the HP-PAVILION DV6 showed a high peak value of 2.34 mG at 10 cm, which decreased rapidly to 0.50 mG at 50 cm. The HP-DLU64QM and DELL-PRESARIO F700 demonstrated similar rapid drop-offs. This steep decline highlights the practical importance of maintaining a proper physical distance from the computer screen. However, it is critical to note that the ideal inverse-square law applies primarily to localized point sources radiating equally in free space. Because computer electronics consist of complex, extended, and distributed internal sources (such as transformers, inductors, and loop wiring), their magnetic field decay rarely follows an exact inverse-square mathematical progression at ultra-close proximity. Instead, very close to the chassis (d < 20 cm), the decay rate often mimics a line or planar source model ($\alpha \frac{1}{d}$). It only transitions closer to the inverse-square law ($\alpha \frac{1}{d^2}$ or even $\alpha \frac{1}{d^3}$ for complex dipole fields) as the measurement distance exceeds the physical dimensions of the internal emitting components.

The high peak emissions recorded from legacy systems like the HP-PAVILION DV6 (2.34 mG) and the HP-KKKH016 align with findings by Bellieni *et al.* (2012). They reported that older-generation portable computers often exceeded 2.0 mG at close proximity due to aging inverter components and less stringent cathode-ray or early LCD shielding protocols. Conversely, the remarkably low emissions from the Apple Macbook Air M4 and Dell XPS 13 represent a significant technological shift. This aligns with Gopal et al. (2021), who found that newer-generation thin-film transistor (TFT) systems achieved an average 70% reduction in stray ELF emissions compared to configurations manufactured a decade prior.

As visually illustrated in Figures 1 and 2, our empirical data confirms that maintaining a standard working distance of ≥ 50 cm substantially reduces magnetic field exposure across all tested devices (Ramirez-Vazquez et al., 2024). Consequently, adopting a conservative operating posture of 50 cm or greater effectively drops ambient ELF exposure to near-background levels. This serves as a highly practical way to implement the Precautionary Principle and the ALARA (As Low As Reasonably Achievable) framework in modern occupational and academic environments.

Table 1: ELF Radiation measured from front computer screen in milligray

S/NO	Types of computers	10cm	20cm	30cm	50cm	100cm
1.	DESTOP-OIGPJ7Q	1.40	0.94	0.24	0.18	0.16
2.	DESTOP-Q4GH51	2.20	1.13	0.89	0.65	0.57
3.	HP PROBOOK 450	0.38	0.27	0.24	0.10	0.09
4.	HP-DLU64QM	2.00	1.53	0.12	0.10	0.10
5.	LENOVO-SLUS7S	0.40	0.34	0.26	0.15	0.13
6.	HP-KKKH016	1.70	1.28	1.19	1.11	1.04
7.	HP-PAVILION DV 6	2.43	2.03	1.64	0.50	0.10
8.	DELL-PRESARIO F700	1.70	1.64	0.93	0.45	0.05
9.	APPLE MACBOOK AIR M4	0.05	0.04	0.03	0.02	0.01
10.	DELL XPS 13	0.06	0.05	0.03	0.O2	0.01
	Mean	**1.23**	**0.92**	**0.55**	**0.33**	**0.23**

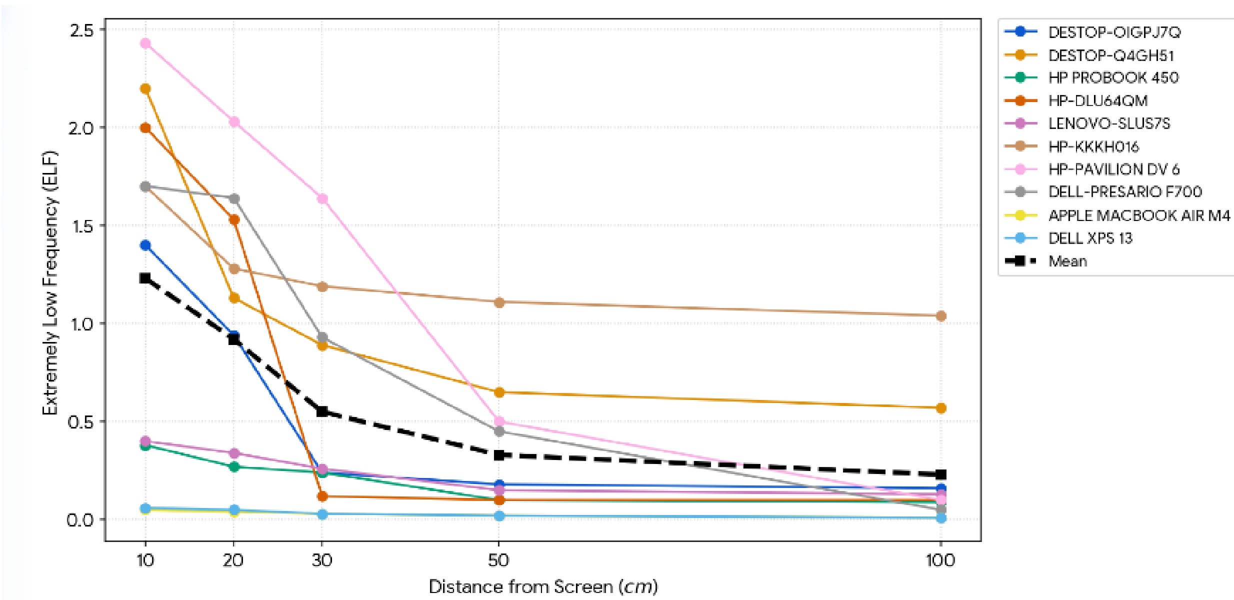

Figure1: ELF Radiation measurement from front computer screen

Table 2: ELF Radiation measured from back computer screen in milligray

S/NO	Types of computers	10cm	20cm	30cm	50cm	100cm
1.	DESTOP-OIGPJ7Q	0.24	0.23	0.21	0.16	0.12
2.	DESTOP-Q4GH51	0.34	0.27	0.24	0.07	0.04
3.	HP PROBOOK 450	0.15	0.10	-	-	-
4.	HP-DLU64QM	0.40	0.27	0.25	0.20	0.03
5.	LENOVO-SLUS7S	0.12	0.10	0.09	0.06	0.04
6.	HP-KKKH016	0.88	0.65	0.50	0.40	0.30
7.	HP-PAVILION DV 6	0.70	0.43	0.08	0.04	0.01
8.	DELL-PRESARIO F700	0.90	0.65	0.40	0.03	0.02
9.	APPLE MACBOOK AIR M4	0.03	0.02	0.02	0.01	0.01
10.	DELL XPS 13	0.03	0.02	0.01	0.01	0.01
	Mean	**0.38**	**0.27**	**0.18**	**0.09**	**0.06**

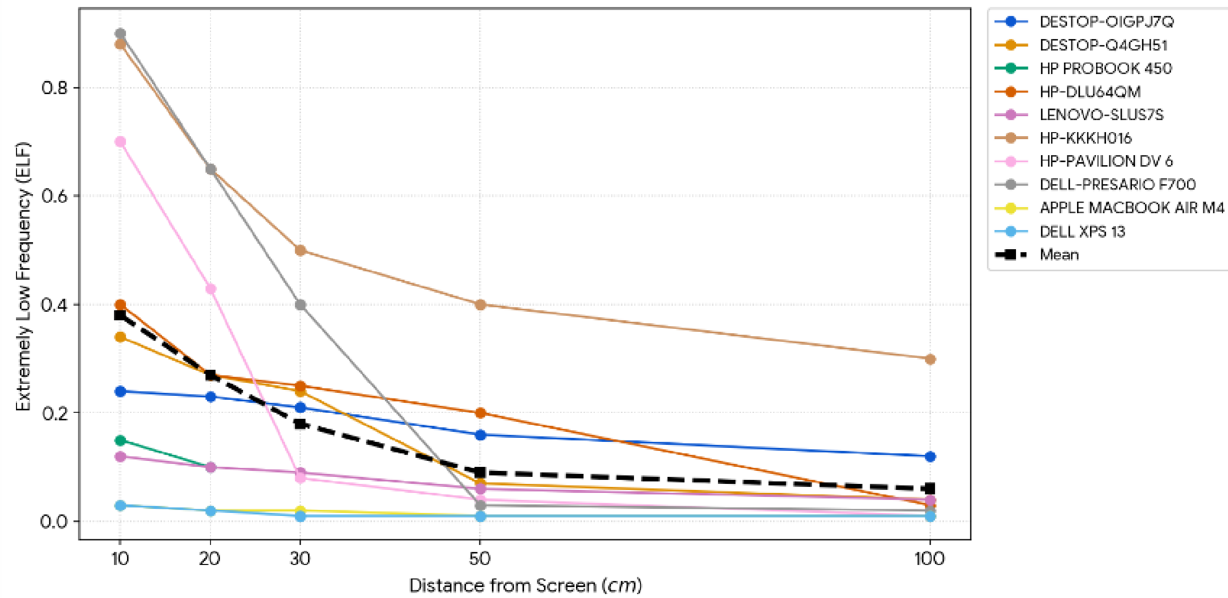

Figure 2: ELF Radiation measurement from back computer screen

CONCLUSION

This study measured and analyzed the weak magnetic fields (ELF fields) coming from ten different computers. The data showed that the front of the computers always gave off more radiation than the back. At a close distance of 10 cm, the average front reading was 1.23 mG, while the back averaged only 0.38 mG. This difference happens because front screen parts lack shielding, while the back has a protective metal cover. Additionally, older computers had much higher emissions than newer ones, like the Apple Macbook Air M4 and Dell XPS 13. Newer designs use lower voltage and Light-Emitting Diode (LED) screens, which successfully lower radiation. The highest reading found was 2.34 mG from an older HP Pavilion laptop. This is still far below official international safety limits. However, distance matters a lot. This is because computer screens are large and complex, radiation levels drop slowly very close to the screen, but they drop much faster as you move away. Sitting at a normal working distance of 50 cm or more reduces your exposure to almost zero. Following this simple habit is a practical way to stay safe and keep your long-term radiation exposure as low as possible.

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