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Electromagnetic Field (EMF) Profile and Baselines at a Non-Haunted Control Location

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HIGHLIGHTS

It is commonly assumed that unusual electromagnetic fields (EMFs) characterize 'haunted' sites, but long-term monitoring likewise found complex EMFs at a 'non-haunted' house.

ABSTRACT

There has been little to no environmental and experience data collected at randomly selected non-haunted control sites despite the call for researchers and field investigators to do so over twenty years ago. Electromagnetic Fields (EMFs) and their association and correlation with haunted locations and haunt-type phenomena have been studied by both academics and hobbyist ghost hunters/paranormal investigators. The field has progressed over the years with mixed results and some within site controls. However, there is still a lack of data collected at non-haunted control locations, and many questions remain on how to collect and analyze baseline data. The current study was conducted to collect multi-hour multiple-run baseline EMF data to explore EMF profiles and to better understand how EMF readings can vary temporally across a 3-axis EMF meter at a non-haunted control site. Results showed that a non-haunted control site had complex time-varying magnetic fields during long-term data collection periods at various days and times, similar to locations deemed to be anomalous. Limitations of the study are noted, and future research is suggested.

KEYWORDS

EMF, haunted locations, baseline locations, haunt phenomena, measurement.

INTRODUCTION

Houran and Brugger (2000) noted that data collected during investigations of haunting and poltergeist cases is limited due to the absence of data from independent control sites. They recommended; "...that field investigators study events that occur at randomly selected control sites whose salient characteristics match those of the target sites, as well as for each investigation of a target site try to set up a control investigation of a similar house whenever possible" (p. 41). Despite this call to action, there has been little to no data collected at randomly selected control sites outside of target research sites (Dagnall et al., 2020).

Field research investigating the potential link between magnetic fields and locations where people have reported haunt-type phenomena has been ongoing for the last several decades (Braithwaite, 2004; Braithwaite et al., 2004; Braithwaite & Townsend, 2005; Laythe &

Houran, 2019; Laythe et al., 2017; Laythe & Owen, 2013; Maher, 2000; Roll & Persinger, 2001; Terhune et al., 2007; Wiseman et al., 2002; Wiseman et al., 2003). These prior studies have mainly examined magnetic fields in target areas within site baselines and controls.

However, the results of these studies have been varied in terms of significant findings for both mean and variance. For instance, Maher (2000) found no significant differences in peak and mean magnetic field magnitudes, while Roll and Persinger (2001) found that the magnetic field strength varied spatially throughout a reportedly haunted location. Wiseman et al. (2002) showed an overall significant relationship between variance in the magnetic field strength and unusual experiences when data from two locations at Hampton Court Palace were combined. Post-hoc analysis indicated a significant difference in mean field strength in The Haunted Gallery, while data from The Georgian Rooms showed significant results for variance but not for the mean magnitude of EMF. Another study by Wiseman et al. in 2003 conducted research at two locations – Hampton Court Palace and the South Bridge Vaults in Edinburgh. They found a significant correlation between variance in the strength of the magnetic field and the number of unusual experiences at Hampton Court Palace but no correlation between either mean magnetic field strength or variance and unusual experiences. Relatedly, magnetic field strength, variance, and pulsing was found to be different in a bedroom at Muncaster Castle when comparing the head of the bed, where people reported numerous anomalous experiences, to the center of the bedroom (Braithwaite, 2004; Braithwaite et al., 2004).

Additional studies also compared target sites and control locations outside of the study location. Terhune et al. (2007) conducted a study to analyze contextual variables and the incidence of photographic anomalies at a haunted site and control site. Part of this study was to explore the differences in the EMF mean and variance between inter-site target and control locations and intra-site active and inactive areas of the target site. The results showed a suggestively greater peak magnetic field strength and variability between control and active sites within the same location. However, there was no correlation between photo print anomaly ratings and peak magnetic field or variance. Laythe and Owen (2013) placed EMF meters inside and seven feet outside of the target site and used a distributional approach to analyze the data. Their data showed a significant difference in EMF magnitude and variability between the haunted location and an area just outside of the building. Mean differences inside the location were 50% to 100% greater than outside. They also found that reported objective anomalous phenomena were significantly associated with serial magnitude spikes. The significance was driven by EMF expansion (i.e., five or more serial spikes in a second happening more frequently than expected).

However, more recent studies showed a correlation between subjective and objective anomalous experiences with EMF variability (Laythe et al., 2017; Laythe & Houran, 2019), replicating the findings from Laythe and Owen (2013) above. Variability was analyzed by assessing EMF-expansion or EMF-suppression, defined by the number of spike 'hits' (**+/-** 2-3 standard deviations) per unit of time before, during, or after the subjective or objective experiences.

ARIGS, Citizen Scientists, and EMF Measurement

Despite the above, research into the potential role of magnetic fields at ghost and haunt locations has not been restricted to academics conducting formal research studies. Hobbyist ghost hunters and paranormal investigators have also explored the potential correlations between magnetic fields and ghost and haunt phenomena. However, substantial issues remain with citizen scientist groups and the appropriate use of the equipment necessary to measure EMF.

Equipment is often used by Amateur Research and Investigation Groups (ARIGs) during ghost hunts (Baker & Bader, 2014; Booker, 2009; Hill, 2017; Hill, 2010; Houran, 2017; Potts, 2004). Electromagnetic Field (EMF) meters are discussed in ghost hunting guides and are used extensively by ARIGs (Hill, 2017; Parsons, 2015; Radford, 2017; Taylor, 2007). However, EMF meters have mainly been used inappropriately during ghost hunts and paranormal investigations, especially regarding the collection of controls (i.e., have not collected data in non-haunted locations) and the formulation of baseline data (Biddle, 2017; Radford, 2017).

The most common meters used by ARIGs include the Safe Range EMF (commonly known as the "K2"), the Lutron EMF-822A, the Mel-Meter, and the Cell Sensor (also known as "The Ghost Meter"). These are all single-axis meters, meaning they either aggregate the readings from three axis to provide one overall "estimate" of EMF magnitude or represent the magnitude of an electromagnetic field on one axis at a specific time. Notably, a meter truly only measuring one axis always contains errors in its readings, as the variation of the other two axes will contaminate the "single axis reading", due to the variation and change of the magnitude of the other axes. Over the previous decade, general observations indicate these meters are most often held firmly in one position and are not rotated on any axis, much less all three. Again, when these meters are genuine ‘single-axis’ meters, they require the user to rotate the meter on all three axes – X, Y, and Z – and calculating the average magnitude with the following equation MAGNITUDE = $\sqrt{X^2+Y^2+Z^2}$, usually within a +/-5% accuracy.

The overarching point is that slight differences in the orientation of the meter can cause drastic changes in the measurement of magnitude displayed by the meter because of both the position of the meter in relation to X, Y, and Z axis, as well as the aggregation process. For example, while rotating a Mel-Meter on a single axis next to a microwave oven (plugged in but not active), measurements ranged erratically between 0.3 mG to 70 mG. As a more formal example of the above, Laythe and Houran (2019) showed significant changes in both single-axis and sum of all three-axis measurements during anomalous perturbation of a target object. Therefore, multi-axis sensing EMF readings and data logging are preferred as they are more precise and detailed for an accurate understanding of EMF activity in the environment.

It is standard practice for ghost hunters (ARIGs) to arrive at a suspected haunted location and begin collecting measurements for baseline readings, which most often consist of a single electromagnetic field (EMF) meter. This activity usually consists of moving from room to room with the meter held in an outstretched hand, taking note of any high and low readings. This activity is performed either during setup of the ghost hunter’s equipment or immediately after setup is complete, and usually takes approximately ten to twenty minutes to complete. Whatever readings are obtained during this short time become the standard in which future readings are compared and how anomalies are determined. ARIGs are under the impression that this common practice provides accurate readings to establish a reliable baseline for later comparison. However, from above, it should be clear to the reader that single-axis handheld readings are confounded by both single-axis aggregation and positioning. Further, EMF readings, baseline or not, can and do change over time (see Laythe & Owen, 2013, for an example).

Further, there are a plethora of events that can affect mains frequency EMF readings, from automatic lights turning on/off, cooling and heating systems cycling On/Off, automated machines, pumps, radio interference, refrigeration units cycling power, and so on. Regarding mains frequency powered appliances in a home, faulty/damaged wiring and electrical overload can lead to power surges, increasing EM field strength (“5 Causes of Power Surging,” n.d.). Internal power surges are also caused by devices that cycle On and Off throughout the day, such as refrigerators and air conditioners. The extra drain on the electrical system is most often noticed at night when the lights are On and are observed dimming, particularly in old or faulty electrical wiring. This is due to electricity being diverted from other appliances (the observed lights) to the high demand of the A/C unit or refrigerator (“Power Surges Cause & Effect,” n.d.). All these variables, and more, need to be considered and accounted for in the data collection and analysis method being used by citizen scientists as some factors may not affect readings in a meaningful way, yet EMF environmental context, in terms of faulty high-power appliances, can easily confound readings despite the above.

There are several factors besides standard electrical appliances, that will also affect the readings obtained by EMF meters, such as distance from the EMF source, due to the Inverse Square Law (Tipler, 1987) and the amount of electrical current passing through the electrical lines and their potential shielding. Generally, EMF-generating sources decay at about a power per foot (i.e., 100 mG is 10 mG at a foot away) (Thide, 2004; Tipler, 1987). It is a common myth that powerlines and other large sources of EMF flood the environment (cf. Laythe et al., 2017). An understanding of the inverse square law would mean that intruding sources of EMF greater than five to ten feet away will not typically impact the magnitude readings of the EMF meter. It is also important to acknowledge that EMFs not only have a magnitude but direction. EMFs can be either vectors or fields, and they are comprised of both electric and magnetic vector fields. The direction of the induced EMF is determined by the right-hand rule. The

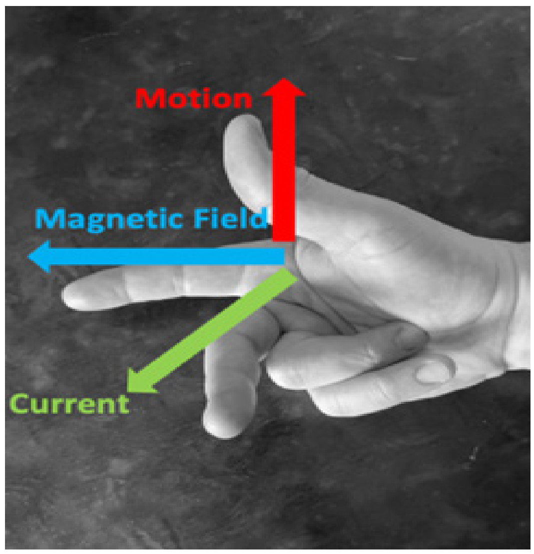

Figure 1. The thumb is the direction of motion of the conductor, the index finger is the magnetic field direction, and the middle finger is the direction of the induced current. Each finger describes one of the three dimensions.

thumb is the direction of motion of the conductor, the index finger is the magnetic field direction, and the middle finger is the direction of the induced current. Each finger describes one of the three dimensions and is perpendicular to each other (see Figure 1). Therefore, the context of the environment is very important, and perhaps more so than the precision of the measurements. The distance of the source of the field from the meter and the vector of the field in relation to the meter results in the magnitude measurement (Tipler, 1987).

To summarize, improper use of equipment and data collection with EMF meters, as well as a lack of baseline and control data collected over time to provide an appropriate testable sample, leads to difficulties in drawing any conclusions about the relationship between anomalous phenomena and EMF data collected in haunted locations. In essence, without appropriate baseline measurements, how does one know that a specific EMF reading is abnormal? Further, and without comparison samples, why would EMF readings in a haunted location be considered anomalous?

The current study addressed some of the above questions by collecting multi-hour multiple-day baseline EMF data within a non-haunted location. From this process, we explore the EMF profile of said baseline location in order to both compare and examine the extent to which EMF magnitude and variability are actually different within a non-haunted control site.

METHODS

Data Collection

EMF data was collected in a non-haunted location in Round Lake, Illinois on January 2nd, 2020 from approximately 6 am to 10 am and 8 pm to 12 am and January 3rd, 2020 from approximately 6 am to 10 am and 8 pm to 10:30 pm. The house is in a subdivision and is approximately 20 years old. It is a two-story home with an unfinished basement, central air, natural gas heat, and Wi-Fi. The owners also have multiple cell phones, tablet computers, and TVs connected to cellular networks and/or the Wi-Fi network. Data was collected by the first author.

Apparatus

EMF Meter. Electromagnetic Field data was collected using a 3-axis Taishi EMF Meter model TES-1393 with the following specifications: sample time of 0.5 seconds; bandwidth 30-2000 Hz; range 20/200/2000 mG; resolution 0.01/0.1/1 mG; accuracy +/- (3%+3d) at 50/60 Hz, +/- (5%+3d) at 40-200 Hz, -3dB at 30-2000 Hz. The meter was positioned with the X-axis in the W-E position, Y-axis in the N-S position, and Z-axis in the UP-DOWN position. Data were collected at a rate of one sample per second with the supplied software with a Dell Inspiron Mini 10 running Windows XP Home Edition.

Procedure

EMF data was graphed, and descriptive statistics were calculated using Microsoft Office 365 Excel. $MAGNITUDE_{EMF}$ was calculated using the formula $MAGNITUDE_{EMF} = \sqrt{(X^2 + Y^2 + Z^2)}$. An Analysis of Variance (ANOVA) was conducted to determine if the difference between the means of $MAGNITUDE_{EMFs}$ for the different days and AM/PM runs were statistically significant (alpha = 0.01). The overall effect size was calculated with Eta-squared, $\eta2 = SS_{Effect}/SS_{Total}$. Cohen's d for unequal sample size was calculated for mean differences. Further, variance analysis was done by determining the percentage of readings that were **+/-** 2 SD during each hour of the four different data collection periods. Levene's test was used for testing inequality of variance for the overall data collected during each time period.

EMF frequency was determined using a 3-axis Fluxgate Magnetometer Model 539 with APS software with the following specifications: range -650 mG to +650 mG; accuracy +/-1% full scale. The meter was positioned with the X-axis in the N-S position, Y-axis in the W-E position, and Z-axis in the UP-DOWN position. It was set to collect approximately 250 samples per second. Data was analyzed by FFT analysis using SigView software.

RESULTS

Firstly, an FFT analysis of the Fluxgate Magnetometer EMF data was conducted. Results show that the only frequency present in the data was 60 Hz, which was expected since this is the mains electrical current power frequency commonly used in the United States. As such, inferences about geo-magnetic field magnitude and variation should not be inferred from the current research. Table 1 shows the summary statistics for the four data collection periods of EMF at the baseline location. All data runs showed leptokurtic distributions with various levels of positive skewness. When this data was compared in clusters (approximately 4 hours per session) with an Analysis of Variance, results of ANOVA indicated the difference between these grouped time periods aggregate means was statistically significant, $F(3,54465) = 1282.67$, $p < 0.01$, with an effect size (Cohen's d) of 0.066, considered a medium effect size (Cohen, 1988; Miles & Shevlin, 2001). However, we caution the reader in terms of overestimating significance, as the large sample size for the ANOVA allowed for significant results despite the small actual

Table 1. Summary Statistics for Four Periods of Temporal Data Collection at a Baseline Location.

	N	Mean	SD	Median	Min	Max	Skew	Kurtosis
Jan 2, 2020 am	15093	2.23	0.66	2.13	0.93	19.5	4.05	58.78
Jan 2, 2020 pm	15125	2.43	0.85	2.27	0.99	12.71	1.81	8.35
Jan 3, 2020 am	15139	2.2	0.73	2.05	0.94	14.17	2.15	15.01
Jan 3, 2020 pm	9112	2.74	0.69	2.68	1.38	14.58	4.79	59.87

changes in the mean magnitude of no more than 0.5mG at the different data collection time intervals (see Table 1). The mean $MAGNITUDE_{EMF}$ percent change for each time interval and corresponding Cohen's d were 10.66% (Cohen's d = 0.76) Jan. 2 am vs. Jan. 2 pm; -1.35% (Cohen's d = 0.69) Jan. 2 am vs. Jan. 3 am; 22.81% (Cohen's d = 0.67) Jan. 2 am vs. Jan. 3 pm; -10.86% (Cohen's d = 0.79) Jan. 2 pm vs. Jan. 3 am; 10.95% (Cohen's d = 0.79) Jan. 2 pm vs. Jan. 3 pm; and 24.49% (Cohen's d = 0.71), Jan. 3 am vs Jan. 3 pm. Cohen's d indicated effect sizes were between medium and large. However, we again emphasize that the practical significance between magnitude and time period are factually small.

The sample variance for each $MAGNITUDE_{EMF}$ time interval was 0.44 for Jan. 2 am, 0.73 for Jan. 2 pm, 0.54 for Jan. 3 am, and 0.47 for Jan. 3 pm. The percent difference between each time period variance, defined as ($T_{2\ Sample\ Var}$ – $T_{1\ Sample\ Var}$)/ $T_{1Sample\ Var}$, were: 66.10% Jan. 2 am vs. Jan. 2 pm; 22.93% Jan. 2 am vs. Jan. 3 am; 8.01% Jan. 2 am vs. Jan. 3 pm; -26.02% Jan. 2 pm vs. Jan. 3 am; -35.01% Jan. 2 pm vs. Jan. 3 pm; and -12.15% Jan. 3 am vs. Jan. pm. This showed that even though the numerical variance difference for each time period was small, there was a large (-35.01% to 66.10%) percent difference between them. Levene's test for inequality of variances was significant ($p < .01$) for the $MAGNITUDE_{EMF}$ readings, which indicated statistically significant unequal variances across the four different time periods data was collected.

The data was analyzed to better understand the temporal variation and how it would compare to a normal standard distribution by examining the percentage of the overall $MAGNITUDE_{EMF}$ readings and the percentage of readings in one-hour intervals that were **+/-** 2 SD. The percent of $MAGNITUDE_{EMF}$ readings for all time intervals that were **+/-** 2 SD were 2.49% for Jan. 2 am, 3.39% for Jan. 2 pm, 6.21% for Jan. 3 am, and 3.94% for Jan. 3 pm. Hour-by-hour comparisons in the percentage of readings that were **+/-** 2 SD was also analyzed to better understand the temporal variability in the $MAGNITDUE_{EMF}$.

Table 2 shows the percentage of readings that were **+/-** 2 SD by the hour and the total time for each data run. The percentages ranged from 0.39% to 14.69%. Notably, the Jan. 2 pm hour 1, Jan. 3 am hours 1 and 3, and Jan. 3 pm remaining time periods of a baseline reading show large degrees of variability beyond a normal distribution of EMF readings, which without interference, would approximate 5%. As the current dataset shows, these percentages are exceeded in several instances, suggesting that baseline readings may not differ from purportedly haunted environments in terms of extreme variability.

Figure 2 shows the $MAGNITUDE_{EMF}$ readings per second for each data run. There was a high level of variability in

Table 2. Percent of Readings +/- Two Standard Deviations By Hour For Total Time

	Jan. 2, 2020 am	Jan. 2, 2020 pm	Jan. 3, 2020 am	Jan. 3, 2020 pm
Hour 1	1.89%	11.69%	14.69%	1.64%
Hour 2	2.75%	0.69%	0.72%	0.61%
Hour 3	1.56%	0.39%	10.00%	na
Hour 4	0.75%	1.25%	0.56%	na
Remaining	1.83%	1.10%	0.68%	14.54%
Total Time	2.49%	3.39%	6.21%	3.94%

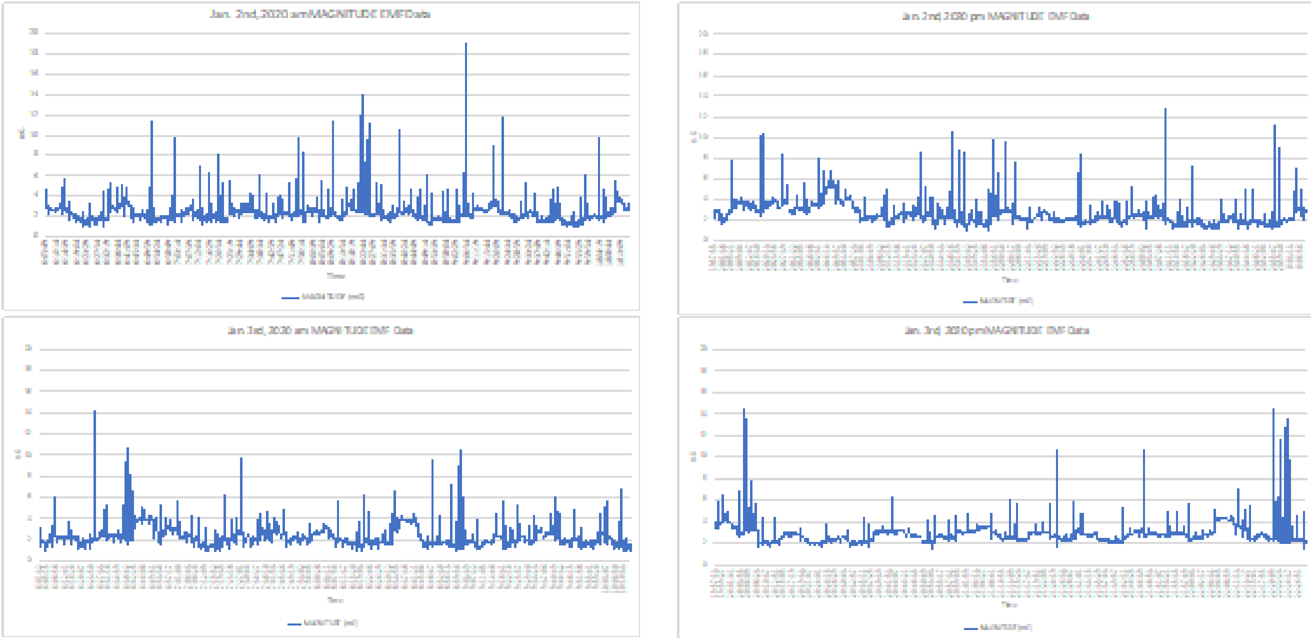

Figure 2. MAGNITUDE$_{EMF}$ data plotted vs. time. Note that the data from left to right ranges from January 2nd to January 3rd, 2020 in approximate 12 hour blocks.

the readings, as seen with the numerous spikes in all data collection periods.

There was considerable variation in the EMF levels in the X and Z axes, which would have been oriented in the W-E and UP-DOWN positions, respectively. There were relatively low readings in the Y-axis readings (N-S) during all data runs. Post-experiment testing confirmed that the Y-axis on the EMF meter was working properly.

Figure 3 shows the difference in what the reading would have been using a single-axis vs. a three-axis sensor meter when placed in the X, Y, and Z-axis orientation. The single-axis meter would have given different readings based on how the meter was oriented in space, while the three-axis meter provided the MAGNITUDE$_{EMF}$ reading no

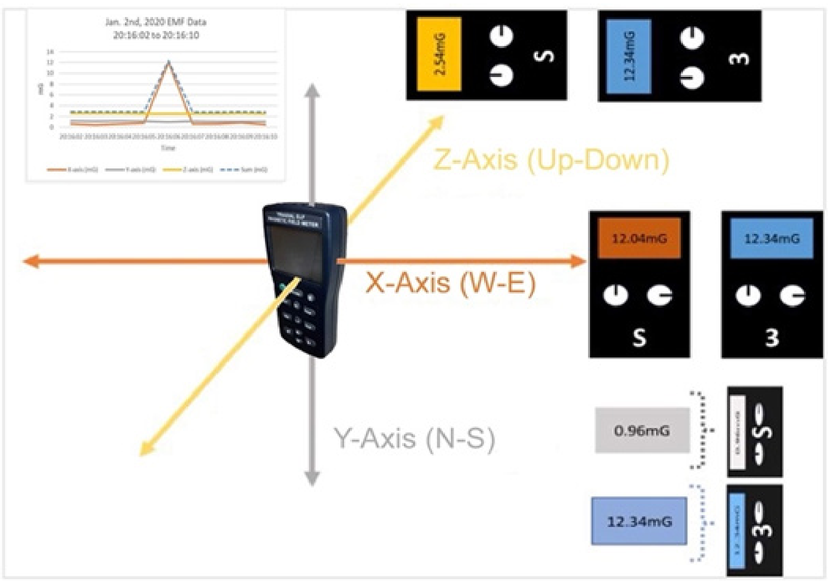

Figure 3. Single axis (S) vs. three axis (3) EMF meter readings on individual axis for an EMF "spike" on Jan. 2nd, 2020 at 20:08:16. The screen color on the single-axis meter matches the three different orientations of the meter and the different axes readings on the graph in the upper left corner. I.e. If the single-axis meter is oriented in the UP-DOWN position, then the reading is 2.54mG, seen on meter screen and the graph. The three-axis meter gives a reading of 12.34mG as all three axes are taking readings and it is calculating the MAGNITUDE.

matter what orientation it was in due to the three different orientations of the three sensors in the meter.

DISCUSSION

The current study shows that a non-haunted control site had complex time-varying magnetic fields during long-term data collection periods at various days and times while the EMF meter was in a fixed position. The differences between the data collection periods were significantly different in both means and, in some cases, extreme in EMF variance. The EMF profile showed that the $\mathrm{MAGNITUDE}_{\mathrm{EMF}}$ levels were like that expected in homes with numerous electronic devices (Gauger, 1985; Silva, 1988). One study of 24 houses by Mader et al. (1990) reported that the measured magnetic field ranged from 0.27 mG to 30.83 mG. Detailed data collection in one house over a week showed that the EMF varied between 0.8 mG to 7.0 mG. The hourly averages were 4.4 mG with a standard deviation of 0.12. The authors also noted that the short-term monitoring had spikes in the EMF that were 400% higher than expected (Mader et al., 1990). The current study showed a $\mathrm{MAGNITUDE}_{\mathrm{EMF}}$ range of 0.93 mG to 19.05 mG with a standard deviation between 0.66 to 0.85 and a higher-than-expected percentage of readings that were **+/-** 2 SD when compared to a normal standard distribution for both individual readings and hour by hour comparison.

In fact, the temporal variation of the EMF data was also similar to that found for EMFs recorded over long periods of time in a reportedly haunted location (Persinger & Koren, 2001). In 1996 Persinger and Koren investigated a house with a variety of haunt-type phenomena reported – nightmares, someone touching the wife and husband's feet, anomalous sounds of breathing and children playing, flashes of light, shadows, sensed presence, waves of fear, and apparitions. The aforementioned house had numerous electronic devices. Persinger and Koren said, "Living in the house was analogous to living in a complex electromagnetic coil with very aberrant application geometries" (p. 185). They measured the magnitude of the main's power (60 Hz) over a 24-hour period. The mean magnitude varied between 2 mG to 40 mG in the basement and the area next to the bed. The EMF mean magnitude recorded over 24 hours on June 19, 1996, showed a variety of spikes and dips, which indicated the field was amplitude modulated.

As stated before, differences in mean and variance have been found between areas where anomalous activity has been reported and within site control areas at reportedly haunted locations (Braithwaite, 2004; Braithwaite et al., 2004; Nichols & Roll, 1998; Wiseman et al., 2002; Wiseman et al., 2003). Differences in mean and/or variance have also been noted between haunted locations and control sites outside haunted study locations (Laythe & Owen, 2013; Terhune et al., 2007).

From above, and when examining our dataset from a non-haunted location, the variance showed stronger absolute differences (8.01% to 66.10%) compared to absolute mean changes (1.35% to 24.49%). The percent readings **+/-** 2 SD overall was 2.49% to 6.21%. The hourly percentages were between 0.39% to 14.69%. This is not much different from the 0% to 11% reported by Laythe et al. (2017) but does not entirely conform to the approximate 2.5% "spikes" in both tails of a normal distribution.

The above changes in a baseline sample could be from meter placement and related appliances, notably if they were placed within one or two feet from such an object, but the inverse square law of EMF decay makes this unlikely. Further, any field placement of EMF will, by its nature, be complex and prone to error due to numerous potential sources. However, one prominent point of this study is that, at least from this baseline sample, non-haunted locations seem more similar than different from EMF data collected in purportedly haunted locations.

Interpretation of potential correlations between magnetic fields and anomalous experiences at reportedly haunted locations and the identification of an individual EMF reading as being anomalous, even if within the site and external site controls are used, would seem to be further complicated if control sites (both non-haunted and within site haunted) show temporal variations and differences in overall mean and variance as this study has demonstrated. How, then, can it be determined what is anomalous vs. baselines and controls? Will any stretch of time be sufficient for baselines and controls? We humbly submit that general magnitude and variability comparisons over time may not gain citizen scientists nor research scientists relevant findings, particularly if the goal is further investigation of the EMF-phenomena hypothesis.

However, the distributional approach to EMF analysis was recently developed and applied to haunt research involving EMF and physical variables and objective and subjective phenomena. Binomial probability analysis methodology was effectively applied to analyzing magnetic field data in locations where contamination could not be controlled (Laythe et al., 2017; Laythe & Houran, 2019; Laythe & Owen, 2013). Most importantly, the above research represents the analysis of EMF magnitude and variability in temporal association with documented and observed anomalous phenomena. As such, and from the similar variabilities and magnitudes collected with the current study as baseline data, the current evidence supports that time-synced readings of EMF in conjunction with documented phenomena may well be more fruitful for replicating the above research. Notably, broad, long-term readings of EMF are unlikely to note any real association with ostensible anomalous phenomena. If one accounts for the overall measurement error of field laboratories, it is likely always the case that various degrees of electronic devices, bad wiring, or related confounds will create variability in any field-measured EMF environment.

In sum, overall temporally extended data sets of haunted environments and the related mean and variance analysis which follows them should be moved away from as imprecision is always going to be present. Therefore, specific spikes in temporal association with subjective or objective phenomena should be analyzed. However, we do note that the current study indicates that EMF variability and spiking occur both in haunted and non-haunted locations but not with the same level of variability present in hour-to-hour comparisons reported by Laythe & Owen (2013). This suggests that abnormal degrees of spikes are likely standard in all EMF environments.

Applied practically, the current findings suggest that while handheld mapping of EMF environments is still useful for gauging potential contamination in a site, citizen scientists interested specifically in the EMF-phenomena hypothesis will need to invest in long-term data logging EMF equipment, preferably 3-axis *and* have the technological capacity for objectively capturing (and time stamping) objective and subjective haunt phenomena in the environment.

Suggested Future Improvements on EMF Survey of Non-Haunted and Reportedly Haunted Sites

There were a few limitations of the current study. First, data was collected in only one location and only in one area of this single location. As such, future validation of baseline data would be greatly bolstered by recruiting additional interested citizen scientists to collect several datasets of baselines to confirm our above conclusions. Secondly, a formal and standardized method of collecting anomalous experiences should be used across these interested parties, such as the "Survey of Strange Events," even in non-haunted control locations (Houran et al., 2019). Third, future studies may benefit from collecting data when the main power to the house was turned off to see to what extent the magnitude and variation of an EMF baseline profile looks like. However, we would be remiss to note that Laythe and Owen (2013) demonstrated large degrees of variability, with no direct power available to the location. Indeed, future studies with standardized procedures could apply and examine several conditions, including haunted or not haunted, inside versus outside, sacred space versus non-sacred space, and in perfect world locations with similar and different architecture. In fact, we heartily encourage amateur enthusiasts interested in such a project to contact us.

Implications and Applications

Long-term EMF data collection and data logging with stationary three-axis meters, as those used in this study, is imperative in collecting quality data when trying to understand the potential correlations between EMF and anomalous activity at reportedly haunted locations. The methods and equipment used in this study are superior to the handheld meters that are used by many ARIGS. Collecting data in control locations with no reported anomalous activity will provide important baseline control data that will assist in determining what might be anomalous readings at a reportedly haunted location. The methods and findings in this paper will benefit and hopefully motivate amateur investigators to collect quality data in order to become citizen scientists and contribute to the big data collection and analyses that are needed to understand the possible correlations between EMF and anomalous activity at reportedly haunted locations.

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AUTHOR CONTRIBUTIONS

Dave Schumacher: Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing – Original Draft, Visualization. **Kenny Biddle:** Conceptualization, Writing – Original Draft, Writing – Review & Editing. **Tim Vickers:** Conceptualization, Writing – Original Draft, Writing – Review & Editing.

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