applied sciences

MDPI

Communication

A Wireless System for Monitoring Termite Activity Using Electromagnetic Induction with Non-Looping Method

Zheng Fang [1,2,†], Hongyue Li [1,†], Yuanfei Ma [1], Mei Zhang [1], Siwei Gao [2], Bosheng Chen [1], Junfeng Shen [2,*] and Dayu Zhang [1,*]

[1] College of Advanced Agricultural Sciences, Zhejiang A&F University, Hangzhou 311300, China; 2020801061003@stu.zafu.edu.cn (Z.F.); lihongyue01@vazyme.com (H.L.); m114843@163.com (Y.M.); 20183028@zafu.edu.cn (M.Z.); bchen13@zafu.edu.cn (B.C.)
[2] Zhejiang Dekan Environmental Technology Ltd., Tongxiang 314500, China; gao_sw@163.com
* Correspondence: newmanshen@outlook.com (J.S.); zhangdayu@zafu.edu.cn (D.Z.)
† These authors contributed equally to this work.

Abstract: Termites can cause severe economic damage in households, reservoirs, agriculture, and forests. Monitoring termite activity plays an important role in integrated termite management. A device for the automatic monitoring of termites with high accuracy and reliability is highly demanded. Here, we introduce Dekan electromagnetic induction with non-looping (DEMINL) method and a novel wireless system for the monitoring of termite activities. The system comprises of a termite bait station and a handheld reader. While the wood pieces in the bait station were consumed by termites, the device could generate alarm signals, which are sent to a signal reader (receiver) through radio frequency identification (RFID) and displayed on the handheld reader's screen. Field tests at three locations over a two-year period showed an accurate detection rate of 97.5–98.5%. The DEMINL-based device demonstrated high accuracy and durability in detecting termites, making it suitable for termite monitoring in households, crop fields, forests, and reservoirs.

Keywords: termites; automatic; monitoring; DEMINL; non-looping; electromagnetic induction; integrated termite management

check for updates

Citation: Fang, Z.; Li, H.; Ma, Y.; Zhang, M.; Gao, S.; Chen, B.; Shen, J.; Zhang, D. A Wireless System for Monitoring Termite Activity Using Electromagnetic Induction with Non-Looping Method. *Appl. Sci.* **2023**, *13*, 11956. https://doi.org/10.3390/app132111956

Academic Editor: Thorsten Schwerte

Received: 21 July 2023
Revised: 20 October 2023
Accepted: 27 October 2023
Published: 1 November 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Termites consume wood members of structures and are one of the most destructive insects in households, reservoirs, and agriculture in terms of damage and control costs. The global economic loss due to damage and control mainly caused by termites was more than US$40 billion according to an estimate with 2010 data, and subterranean termites contribute 80% of the total damages [1–3]. Methods to control termites include applying liquid insecticide in the soil surrounding structures to form a uniform and continuous barrier, using slow-acting termiticide powders for the remedial control [4], preparing physical barriers, such as high-grade stainless-steel mesh to prevent termite invasion [3], or utilizing excavation strategies to destroy termite nests [5]. Monitoring and locating the termites is one of the most important processes for these strategies to prevent termite infestation. Termite bait stations can be used for monitoring termite activity and for pest management. Bait stations containing corrugated board or other wood materials are also applied to attract termites, and then termiticides can be applied. Bait stations have become one of termite management methods [6–8]. Unlike traditional liquid insecticides treatment, the adoption of monitoring–baiting stations can reduce termiticide use significantly. Monitoring–baiting stations have been widely used for integrated termite management, especially for termite remedial control [3,9,10]. These stations rely on manual routine inspection to determine the presence of worker termites in or around the wood bait inside the station. However, inspection is labor intensive and may disturb termite activity and give inaccurate information. Monitoring termite activities, especially remote monitoring, plays a very important

role in termite control. Therefore, there is a need for a semi-automatic or fully automatic monitoring system instead of manual baiting stations to reduce the labor and cost. A semi-automatic or fully automatic system that has non-invasive monitoring features would provide useful information on termite activity without manual inspection and could save time and labor especially when inspecting bait stations.

To date, several automatic monitoring devices based on various sensors are available for termite management. The automatic monitoring devices available include those based on an acoustic emission (AE) sensor [11–15], a wireless smart probe [16], a silver particle circuit painted on a wood piece or polyethylene sheet in the termite monitoring–baiting station [17,18], odor detection [19], temperature, gas, and relative humidity detection [20], infrared cameras [21], computer tomography and endoscopy [22], microwave (Termatrac^{TM}, Ormeau, Australia), and so on. For instance, a termite monitoring system using an acoustic emission (AE) sensor has been applied to detect the noise signal of termites feeding on wood materials. Based on acoustic signals generated by termites when attacking wood, using a discriminant analysis, the acoustic feature in the termite detection system could reach an accuracy of 83.75% [13]. But it should be noted that the noise made by termites can be very easily interfered with by ambient sound signals [14]. The accuracy of this AE sensor-based termite monitors is increasing with the help of the developed algorithm and analysis strategies.

The support vector machine (SVM) with polynomial kernel function achieves the best classification accuracy of 0.9188 [14]. Based on a termite bait station, Su (2001) described a sensor consisting of a wooden stake which was painted with a conductive circuit of silver particle emulsion [17]. The sensors were wired to a data logger and a host computer and formed a computerized remote monitoring system. The mean monthly accuracy at 6 months after installation ranged from 41 to 79% [17]. Additionally, when the dimensionally stable sensor was used instead of a wood sensor, the accuracy was significantly improved compared with wooden sensors. The loping circuit is less affected by various environment factors in the dimensionally stable sensor [18]. After this electronic monitoring system was devised and field-tested, an ESP (electronic sensing and protection) monitoring–baiting system was developed. Although the looping circuit-based ESP monitoring–baiting system has been used for termite management, the baiting system is impractical in some large sites, such as agricultural fields. The equipment and routine site visits still remain costly. More important, the mean sensor longevity of the dimensionally stable sensors was only 11.7 months.

An ideal detection system would offer a low cost, simplicity, reliability and ease of termite control. There is room to improve certain characteristics, such as accuracy and reliability. A device for semi-automatic or fully automatic monitoring of termites with higher accuracy and reliability is highly demanded. In this study, we created a system by using a novel Dekan electromagnetic induction and non-looping (DEMINL) method. Electromagnetic induction is the information trigger method in this system. Non-looping refers to the separation of the bait and the electromagnetic circuit board which emits the alarm signal. Instead, the wood bait is just a supporting material as well as the termite food bait. We installed our DEMINL technique-based termite monitor stations at three termite-infested sites in China (Linan, Hangzhou, and Tongxiang), and their accuracy when showing termites' activities was analyzed within two years. Our results exhibited that this system showed high accuracy and reliability in monitoring termite activities. Here, we report this novel monitoring device based on DEMINL technology as well as its application in remotely detecting termite activity.

2. Materials and Methods

2.1. Electromagnetic Induction with Non-Looping Method

The DEKAN electromagnetic induction with non-looping (separation of the bait and the electronics) method (short as DEMINL) is a novel termite monitoring and warning system for detecting termite activity.

The wireless device can detect the presence of termite workers by changes in the magnetic amount during termite feeding activity. Unlike a traditional monitoring system in a baiting station, separation of the bait and the electronics refers to the fact that wood bait does not constitute a part of the electronic circuit; instead, it is strictly only for food and as a supporting material for a magnetic bar in an information trigger block. With respect to the communication approach between the parts of device, electromagnetic induction is used for information triggering, and then signals are transferred to a remote scanner (handheld reader) by radio frequency identification (RFID).

The device based on this method basically constitutes two parts: a bait station and a handheld scanner (reader) (Figure 1). The bait station includes an information trigger block at the bottom and an electromagnetic circuit board at the top (Figure 1A,B). The information trigger block consists of six rectangular wooden bars standing upright. Of the six bars, two have been hollowed inside to contain spherical glass particles (~1 mm in diameter). A permanent magnetic block is placed on the top of spherical glass particles in the hollow (Figure 1A,B).

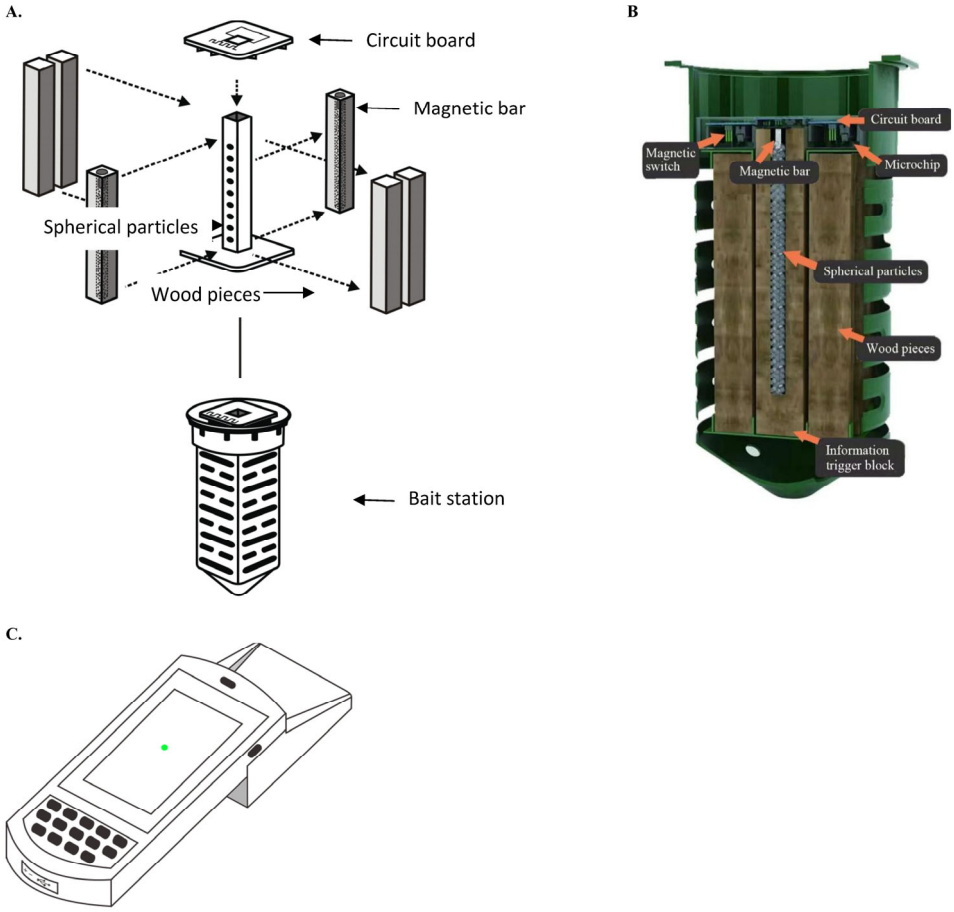


Figure 1. Components of a device using electromagnetic induction with separation of the bait and the electronics method for monitoring of termites. The device consists of two parts. (**A**) Bait station, including information trigger block (wood pieces, spherical particles, and magnetic bars) and circuit board. (**B**) Cross-sectional view of components of a device. (**C**) Radio frequency identification (RFID) signal scanner (reader). The signal can be shown on the screen of the reader (green means no termites).

On the top of the information trigger block is the electromagnetic circuit board, which constitutes the antenna, a magnetic switch (Reed switch), and a microchip (Figure 1A,B). The electromagnetic circuit board is attached closely to the magnetic bar. Termites attracted by wooden pieces consume the outside of the spherical particle-filled information trigger block (Figure 2A). When the information trigger block is broken due to the termites'

consumption, glass beads extrude from the breaking site and the permanent magnetic bar on the top of the beads drops down to active the magnetic switch in the electromagnetic circuit board.

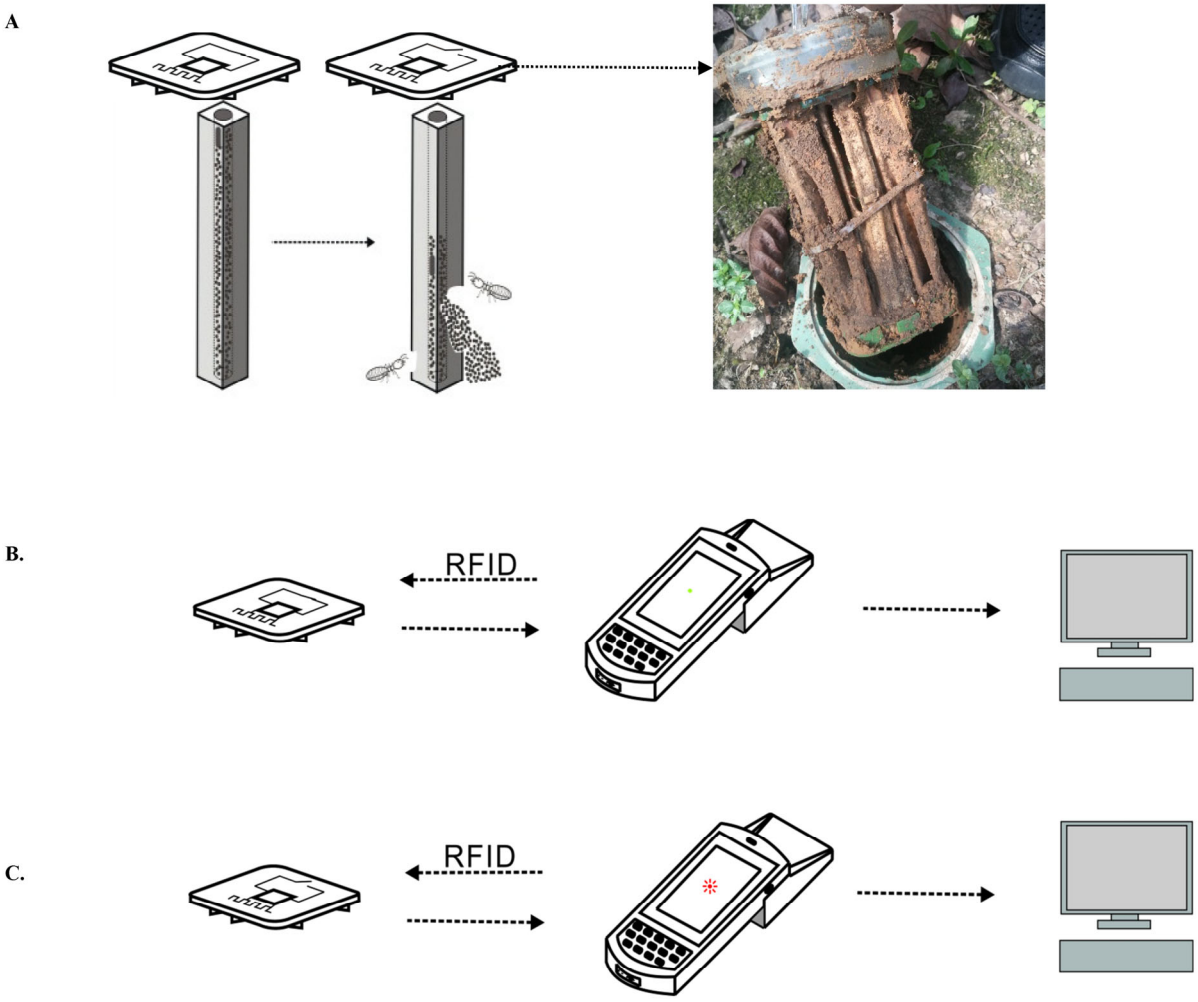


Figure 2. Scheme of how the system works. The magnetic bar drops while the wood piece in the information trigger block is consumed by termites, which causes a warning signal in the circuit board (**A**). The scanner sends a radio signal to the circuit board and the circuit board sends a signal back to the scanner based on radio frequency identification (RFID). The signal can be shown on the screen of the reader with green (no termites) (**B**) or red spots (with termites) (**C**).

Along with the bait station, there is a handheld scanner (reader) (Figure 1C), equipped with a 7.4 V lithium battery inside. The scanner consists of an antenna, a microchip, and an operating system.

To send and receive signals, a RFID (radio frequency identification) method is set up for communication between the circuit board in the bait station and the handheld scanner. This system adopts 465 MHz radio frequency for communication. The radio signals emitted by the handheld scanner's (Figure 1C) antenna at a specific frequency can activate the microchip in the circuit board (which is also called a tag in RFID system), and then the microchip in the circuit board backscatters radio signals so that the status of the circuit board can be read by the reader. The reader will decode the signals and will then show them on the screen of the reader or send them to the PC end for further analysis (Figure 2).

2.2. Warning Signal Generation

When termites extensively consume the wood bars to the hollowed section (Figure 2A), the built-in spherical particles may spill out from the damaged site, and the permanent

magnetic bar on the top drops due to gravity. Then, the magnetic switches (Reed switches) within the electromagnetic circuit board turn off due to the disappearance of magnetic force (Figure 2A). The microchip detects the switch working statue and stores the information on the chip inside. Then, the scanner (reader) can send a radio signal as well as power to the microchip in the circuit board to detect the situation of the microchip in the bait station via RFID. If there are no termites, the screen of handheld reader shows green spots (Figure 2B). The alarm signals, which mean presence of termites, are marked with red spots (Figure 2C). If necessary, the data at the reader can be wirelessly transferred to a PC end associated with a termite management database.

2.3. Test Sites

Field test sites in Linan (LA), Hangzhou (HZ), and Tongxiang (TX) were selected in Zhejiang Province, China. These sites are located between north latitude 30.0–30.6 and east longitude 119.5–120.6. All test sites have a typical subtropical climate characterized by hot, humid summers and mild winters. Termites abundant in these areas include *Reticulitermes flaviceps*, *Odontotermes formosanus*, and *Coptotermes formosanus* [23]. A total of 40, 200, and 250 monitoring–bait stations were installed at the LA, HZ, and TX test sites, respectively. Each test site was equipped with a handheld scanner (reader). All these field tests were conducted during a two-year period of time.

2.4. Device Installation

The monitoring–bait stations were buried underground without concrete or stone foundations at each field test site. A cylindrical pit with a depth of 25 cm and a diameter of 15 cm was excavated in the ground initially. Afterwards, a monitoring–bait station was settled into the pit with the circuit board facing upwards. It is crucial to make sure that the top of the station is aligned well with the ground surface when the pit is filled with soil, as this ensures that the handheld reader is able to detect the monitoring–bait station underground. After installation, the station was marked. The distance between each installed monitoring–bait station was 5–10 m.

2.5. Data Collection and Analysis

To determine the accuracy of the device for detecting termite feeding activity, all bait stations were checked by the signal reader and then followed up by manually opening the covers of stations every three months to examine the status of the information trigger bar and termite presence. The sensor integrity was checked at the same time. If the wood pieces in the information bar were attacked by worker termites, an alarm signal and red spot would appear on the screen of the handheld reader. Accuracy was evaluated by the site inspection results and signal reader's records. Four categories were assigned and recorded according to Su (2002) [18], as follows:

TN (true negative), i.e., information bar intact (no alarm) and absence of termites;
TP (true positive), i.e., alarm signal (red spot) and presence of termites or wood pieces attacked by termites;
FN (false negative), i.e., no alarm with the presence of termites or no alarm with stations destroyed;
FP (false positive), i.e., alarm signal (red spot) and absence of termites.

Two categories of accuracy rate, including accuracy rate (AR)% and accuracy rate of positive signals (ARP)%, were calculated.

Accuracy rate (AR)% = (TN + TP)/(TN + TP + FN + FP) × 100%. Accuracy rate also represents the integrity (longevity) rate of device, which can be used to evaluate the durable character of the device.

Accuracy rate of positive signals (ARP) % = TP/(TP + FP).

Standard normal distribution (Z value) and Wilcoxon signed-rank test (p vaule) of each site were calculated with TN + TP and FN + FP response values using function "z.test" (package "BSDA") and function "wilcox.test" (package "stats") implemented in R 4.1.3, respectively.

3. Results

The field test results proved that the monitoring system and device described here is practical to detect termite activity used at termite bait stations. A total of 40, 200, and 250 baiting stations have been installed at three test sites (LA, HZ and TX). Results at three test sites showed that the accuracy rate was 97.5%, 98.5%, and 98.4%, respectively, at 24 months after installation. Among the stations showing positive signals, there was a more than 95% accuracy rate. After 24 months of application, only one, three, and four stations failed to show true signals at three test sites, respectively, and more than 97% circuit boards were in good condition and fully functioning. The accuracy of monitoring data from the three test sites is presented in Table 1.

Table 1. Performance of the system for detecting termite activities during a 24-month period.

Site	Months	TN	TP	FN	FP	AR%	ARP%	Z	P
LA 40 stations	3	39	1	0	0	100	100	−2.1602	0.0004678
	6	38	2	0	0	100	100		
	9	38	2	0	0	100	100		
	12	37	3	0	0	100	100		
	15	36	4	0	0	100	100		
	18	36	4	0	0	100	100		
	21	35	4	1	0	97.5	100		
	24	35	4	1	0	97.5	100		
HZ 200 stations	3	189	11	0	0	100	100	−8.641	0.0006371
	6	185	14	1	0	99.0	100		
	9	173	25	1	1	99.0	96.1		
	12	156	42	1	1	99.0	97.7		
	15	153	45	1	1	99.0	97.8		
	18	151	47	1	1	99.0	98.0		
	21	149	48	2	1	98.5	98.0		
	24	148	49	2	1	98.5	98.0		
TX 250 stations	3	248	2	0	0	100	100	−5.945	0.0008446
	6	240	10	0	0	100	100		
	9	234	14	2	0	99.2	100		
	12	209	38	1	2	98.8	95.0		
	15	207	40	1	2	98.8	95.2		
	18	201	46	1	2	98.8	95.8		
	21	195	46	2	2	98.4	95.8		
	24	194	47	2	2	98.4	95.9		

TN (true negative), information bar intact (no alarm) and absence of termites; TP (true positive), alarm signal (red spot) and presence of termites or wood pieces attacked by termites; FN (false negative), no alarm with the presence of termites or no alarm when stations were destroyed; FP (false positive), alarm signal (red spot) and absence of termites.

There were 40 stations installed in the LA test site (LA). After 2 years, 4 stations showed warning signals for termite presence. Either termites or wood pieces destroyed by termites were found at all these four stations after manual checking. The results also showed that 97.5% of the circuit boards retained their integrity at 24 months after installation, which means these electronic boards have a lifetime of more than 24 months.

At the HZ test site, 200 stations were installed. At 18 months, 151 stations showed true negative results, and 47 stations showed true positive results. One station was false negative, and one station was false positive. At 24 months, 148 stations showed true negative results, 49 stations showed true positive results, 2 stations were false negative, and 1 station was false positive. The accuracy rate of the monitoring system after 18-month and 24-month installation was 99.0% and 98.5%, respectively. Among the stations showing positive signals, 98.0% of stations showed true positive results.

250 stations were installed at the TX test site. Five baiting stations could not be found due to construction after 21 months of operation. At the remaining 245 stations, 4 stations

(1.6%) showed false signals, and all other stations (98.4%) either were true negative or true positive after 24 months of operation.

4. Discussions

A novel method (DEMINL) for detecting termite activity was introduced here. The field tests showed that there was a high rate of accuracy and reliability of products. The rate of accuracy reached more than 97%. Even after a two-year test period, 97% of products still remained intact and functional. All these test results showed that DEMINL is suitable for termite detection. The field tests showed that this system is suitable for detecting different termite species belonging to *Reticulitermes*, *Coptotermes*, *Odontotermes*, and *Macrotermes* et al. Particularly, *R. leptomandubularis*, *R. flaviceps*, *O. formosanus*, and *C. formosanus* were found in the bait stations. These termites are subterranean termites and have similar feeding preferences on wood pieces. We have not tested whether this device can be used for detecting dry-wood termites. According to the feeding activity of dry-wood termites, this device is expected to be effective for monitoring dry-wood termite species too. Since *Reticulitermes* and *Coptotermes* are the main termites damaging wood structures, this system could be very useful in detecting termite activity for households. As well as households, this system can also be used in historic buildings, reservoirs, sea/riverbanks, and agricultural and forest fields, as well as natural parks.

DEMINL technology improves the detection of termite activities due to its unique features. The attractive wood pieces settled in the device can attract termites from the nearby environment, which improve the efficacy of monitoring termite activity. The RFID technique in the device provides the possibility of a real-time alarm message, which enables rapid treatment of termites. More importantly, electromagnetic induction along with the non-looping method makes it possible for the wood pieces in the bait station to be separated from the electronic part, i.e., circuit board. The electronic part can be sealed and made water resistant. Termites, especially subterranean termites, usually occur in warm and humid areas, and water and humidity can affect the quality of electronic units significantly. Moisture-induced broken circuits in sensors can cause numerous false positive events. Therefore, a device with waterproof technology can reduce the false positive rate significantly. Compared with some other remote monitoring devices, such as those based on acoustic emission (AE) sensors, odor detection, temperature, gas, and humidity detection, infrared cameras, or a silver particle circuit painted on a wood piece or polyethylene sheet in termite monitoring–baiting station, this devices based on DEMINL technology has unique characters and offers a new option for remote termite monitoring and management. The device introduced here provides a more stable and precise approach for monitoring termite activity.

False red spots (false positive signals) were found, although the rate was very low (<3%). For instance, one case was found due to a physically broken wood piece caused by fungi infections. After 24 months of operation, we found that some stations were infected by fungi, but most of the wood pieces were still intact and did not cause a false signal. Other cases showing false positives, which made up less than 0.5% of the cases, were due to the breakage of the circuit board and the resulting short circuit. Ants, earthworms, and beetles did appear at some bait stations; however, we have not observed any false signals generated by these organisms, probably because these wood pieces were not damaged easily by these organisms.

In one case (the TX site), there was no alarm signal, but termites were present (false negative). But, at the next check three months later, the positive warning signal appeared. This was because termites started to accumulate and consume the wood, but the consumption at that time was too little to cause positive signals, and only after some additional time (less than three months) were the wood stakes totally consumed by the termites, resulting in the positive signals. This case did not affect the accuracy rate.

RFID is a wireless sensor technology which is used for the identification of locations of monitoring stations [24–26]. The signal is backscattered to handheld reader and the

situation as well as locations can be showed on the reader. The distance between the reader and the tag in the bait station is associated with the frequency range. The device adopts 465 MHz, and the reader can receive the signals from the underground bait stations. The handheld reader is convenient to use due to the efficient distance between the station and receiver. A pest control technician could just hold it to check the station and does not need to bend over and open the bait station. High frequency radio can be used for a long-distance communication if this is necessary.

In the future, a few directions for the development of this system could be considered. For instance, a center database could be launched. All data, including the status of the termite situation from the handheld readers, as well as termite species and degree of damages will be collected, stored, and analyzed. This database will provide some basic information for termite biological studies as well as for pest control. Furthermore, an updated fully automatic termite detecting system could be developed based on the current DEMINL system. For instance, the handheld reader can be replaced by a special base, which can collect information signals from the monitoring stations automatically through a different communication method, such as LoRa or Cat.1 communication technology, and then this information can be automatically collected more frequency, such as on a daily basis. Currently, the handheld reader can detect whether there are termites through showing green spots or red spots; however, it has not integrated into a geographic map showing detailed location information. In the future, geological maps, such as Google Maps, can be integrated, which will be more convenient to use.

Author Contributions: Conceptualization, J.S. and D.Z.; methodology, Z.F., Y.M., M.Z., S.G. and J.S.; validation, B.C., M.Z. and S.G.; investigation, Z.F., H.L., Y.M., B.C., S.G. and J.S.; resources, J.S. and D.Z.; fata curation, B.C.; writing—original draft preparation, B.C., J.S. and D.Z.; writing—review and editing, B.C. and D.Z.; funding acquisition, J.S. and D.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Natural Science Foundation of Zhejiang Province (LZ20C040001), DEKAN-ZAFU collaboration project (2045200423) and the developmental fund of Zhejiang A&F University (2012FR087).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We would like to thank Brian Forschler and William Robinson for their comments and suggestions.

Conflicts of Interest: Authors Siwei Gaio, Junfeng Shen were employed by the company Dekan Environmental Tech Co. The remaining authors declare that the research was conducted in theabsence of any commercial or financial relationships that could beconstrued as a potential conflict of interest.

References

1. Khan, M.A.; Ahmad, W. Termites: An Overview. In *Termites and Sustainable Management*; Sustainability in Plant and Crop Protection; Khan, M., Ahmad, W., Eds.; Springer: Cham, Switzerland, 2018.
2. Rust, M.K.; Su, N.Y. Managing Social Insects of Urban Importance. *Annu. Rev. Entomol.* **2012**, *57*, 355–375. [CrossRef] [PubMed]
3. Su, N.Y. Development of Baits for Population Management of Subterranean Termites. *Annu. Rev. Entomol.* **2019**, *64*, 115–130. [CrossRef] [PubMed]
4. Su, N.Y.; Scheffrahn, R.H. Foraging population and territory of the Formosan subterranean termite (Isoptera: Rhinotermitidae) in an urban environment. *Sociobiology* **1988**, *14*, 353–359.
5. Su, N.Y. Novel technologies for subterranean termite control. *Sociobiology* **2002**, *39*, 95–102.
6. Reinhard, J.; Lacey, M.J.; Lenz, M. Application of the natural phagostimulant hydroquinone in bait systems for termite management (Isoptera). *Sociobiology* **2002**, *39*, 213–230.
7. Lenz, M.; Evans, T.A. Termite bait technology: Perspectives from Australia. In *Proceedings of the 4th International Conference on Urban Pests*; Pocahontas Press: Charleston, SC, USA, 2002; pp. 7–10.
8. Evans, T.A.; Iqbal, N. Termite (Order Blattodea, Infraorder Isoptera) Baiting 20 Years after Commercial Release. *Pest Manag. Sci.* **2014**, *71*, 897–906. [CrossRef] [PubMed]

9. Kakkar, G.; Su, N.Y. Molting Drives Mortality in Foraging Populations of Formosan Subterranean Termites (Isoptera: Rhinotermitidae) Baited with a Chitin Synthesis Inhibitor, Noviflumuron. *Pest Manag. Sci.* **2018**, *74*, 219–224. [CrossRef] [PubMed]
10. Webb, G. Elimination of *Coptotermes lacteus* (Froggatt) (Blattodea: Rhinotermitidae) Colonies Using Bistrifluron Bait Applied through In-Ground Bait Stations Surrounding Mounds. *Insects* **2017**, *8*, 98. [CrossRef]
11. Lemaster, R.L.; Beall, F.C.; Lewis, V.R. Detection of Termites with Acoustic Emission. *For. Prod. J.* **1997**, *47*, 75–79.
12. De la Rosa, J.J.G.; Pérez, A.A.; Salas, J.C.P.; Fernández, J.M.S. A Novel Measurement Method for Transient Detection Based in Wavelets Entropy and the Spectral Kurtosis: An Application to Vibrations and Acoustic Emission Signals from Termite Activity. *Measurement* **2015**, *68*, 58–69. [CrossRef]
13. Nanda, M.A.; Seminar, K.B.; Nandika, D.; Maddu, A. Discriminant Analysis as a Tool for Detecting the Acoustic Signals of Termites Coptotermes Curvignathus (Isoptera: Rhinotermitidae). *Int. J. Technol.* **2018**, *9*, 840. [CrossRef]
14. Nanda, M.A.; Seminar, K.B.; Nandika, D.; Maddu, A. A Comparison Study of Kernel Functions in the Support Vector Machine and Its Application for Termite Detection. *Information* **2018**, *9*, 5. [CrossRef]
15. Nanda, M.A.; Seminar, K.B.; Nandika, D.; Maddu, A. Development of Termite Detection System Based on Acoustic and Temperature Signals. *Measurement* **2019**, *147*, 106902. [CrossRef]
16. Oliver-Villanueva, J.V.; Abián-Pérez, M.A. Advanced Wireless Sensors for Termite Detection in Wood Constructions. *Wood Sci. Technol.* **2013**, *47*, 269–280. [CrossRef]
17. Su, N.Y. A Computerized System for Remote Monitoring of Subterranean Termites near Structures. *J. Econ. Entomol.* **2001**, *94*, 1518–1525. [CrossRef] [PubMed]
18. Su, N.Y. Dimensionally Stable Sensors for a Continuous Monitoring Program to Detect Subterranean Termite (Isoptera: Rhinotermitidae) Activity. *J. Econ. Entomol.* **2002**, *95*, 975–980. [CrossRef] [PubMed]
19. Lewis, V.R.; Fouche, C.F.; Lemaster, R.L. Evaluation of Dog Assisted Searches and Electronic Odor Devices for Detecting the Western Subterranean Termite. *Forest Prod. J.* **1997**, *47*, 79–84.
20. Indrayani, Y.; Yoshimura, T.; Yanase, Y.; Fujii, Y.; Imamura, Y. Evaluation of the Temperature and Relative Humidity Preferences of the Western Dry-Wood Termite Incisitermes minor (Hagen) Using Acoustic Emission (AE) Monitoring. *J. Wood Sci.* **2007**, *53*, 76–79. [CrossRef]
21. Lax, A.R.; Osbrink, W.L. United States Department of Agriculture-Agriculture Research Service Research on Targeted Management of the Formosan Subterranean Termite *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae). *Pest Manag. Sci.* **2003**, *59*, 788–800. [CrossRef]
22. Fuchs, A.; Schreyer, A.; Feuerbach, S.; Korb, J. A New Technique for Termite Monitoring Using Computer Tomography and Endoscopy. *Int. J. Pest Manag.* **2004**, *50*, 63–66. [CrossRef]
23. Ruan, G.; Song, X.; Hu, Y.; Han, N.; Zhang, D. Foraging Activities of *Coptotermes formosanus* in Subtropical Areas in China. *J. Econ. Entomol.* **2015**, *108*, 701–706. [CrossRef] [PubMed]
24. Duroc, Y.; Tedjini, S. RFID: A Key Technology for Humanity. *Comptes Rendus Phys.* **2018**, *19*, 64–71. [CrossRef]
25. Nunes-Silva, P.; Hrncir, M.; Guimarães, J.T.F.; Arruda, H.; Costa, L.; Pessin, G.; Siqueira, J.O.; de Souza, P.; Imperatriz-Fonseca, V.L. Applications of RFID Technology on the Study of Bees. *Insectes Sociaux* **2018**, *66*, 15–24. [CrossRef]
26. Van Geystelen, A.; Benaets, K.; de Graaf, D.C.; Larmuseau, M.H.D.; Wenseleers, T. Track-a-Forager: A Program for the Automated Analysis of RFID Tracking Data to Reconstruct Foraging Behaviour. *Insectes Sociaux* **2015**, *63*, 175–183. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.