DETECTION OF MOVEMENT OF TERMITES IN WOOD BY ACOUSTIC EMISSION TECHNIQUES

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INTRODUCTION

Damage and cost of repairs from termite infestation in homes and other structures in the United States account for approximately 2 billion dollars annually (Ref. 1). Detecting the presence of termites in wood structures is usually accomplished by visual observation of termite waste products, tunneling, and reduction in the density of the wood due to termite activity. Situations exist in all structures where access is limited and wallboard or other coverings restrict the ability to conduct a visual inspection.

It is therefore desirable to have methods other than visual for detecting the presence of active termites. Monitoring the vibrations produced by termites when feeding within the wood is one such method. Several hand held devices based on Acoustic Emission technology have been manufactured over the past 15 years for detecting the vibrations due to feeding but these devices have not had the sensitivity to detect movement of the termites within the cavity. The stress waves produced by termites during feeding are the highest amplitude stress waves produced by an active colony. We have found in our research that an order of magnitude increase in sensitivity is required to detect movement of the Termites. A report published by Scheffrahn et al 1993 (ref 2) gives results of the detection of termites with a hand-held instrument based on Acoustic Emission. Four different types of termites were studied for evaluation of the capabilities of the instrument. It was reported that the instrument was only capable of detecting the feeding termites with a 50% probability at a distance of 50cm from the colony. When the transducer was in close proximity to the colony only 5 to 25 counts/min (1 count = 1 event) were detected depending on the type of termites and density within the colony. They also reported that no difference was observed in the count rate when the colony was agitated by dropping a coin on the wood in the near vicinity of the colony. We have found that agitation causes a large increase in the count rate measured immediately following the agitation. We will show that this large increase in the count rate is due to movement of termites leaving the disturbed area.

This report describes an acoustic emission sensor and instrument that will detect and record the movement of the Termites in their gallery.

THE TRANSDUCER

A photograph of the transducer used for termite movement detection is shown in figure 1. It is a piezoelectric device with peak sensitivity at 40Khz. Operation of the instrument at this frequency is high enough to eliminate low frequency background noise, while being low enough in frequency to minimize attenuation effects in wood structures.

The transducer is calibrated in the displacement mode traceable to NIST. Its sensitivity to displacement as a function of frequency is shown in figure 2. Note that the sensitivity at 40Khz is approximately 1 volt per nanometer. With 60dB of amplification the transducer sensitivity is approximately 1.5 volts per picometer of displacement. The housing for containing the 40Khz transducer and preamplifier was constructed such that a 1/8 inch diameter wave guide could be screwed into one end of the housing. In its final position in the housing the flat end of the wave guide makes contact with the spring loaded transducer. Acoustic coupling between the wave guide and transducer is accomplished by use of petroleum jelly. In this manner either the transducer or wave guide can be independently removed and replaced. The exposed end of the wave guide terminates in a point and 1/8 inch screw threads are present to allow the wave guide to be firmly secured with good internal mechanical contact with the wood. The main body of the probe housing the transducer and a 60dB preamplifier is constructed from Delrin. Figure 3 is a photograph of the probe containing the waveguide, transducer and preamplifier. The main body of the probe has been covered with a sound attenuating elastomer and heat shrink tubing is used to hold the elastomer in place. Coating the probe with this material assists in attenuating airborne signals that might otherwise be detected.

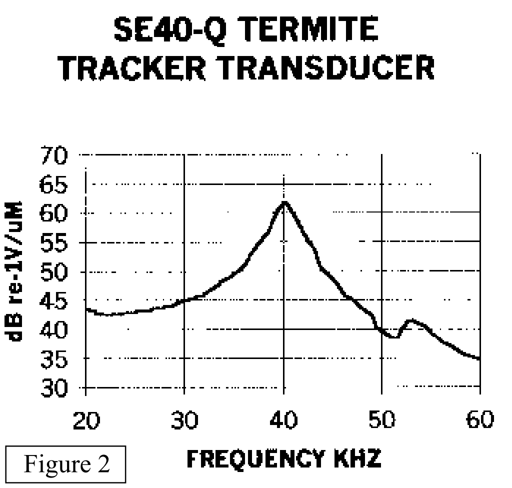


Figure 2

The use of a wave guide as opposed to mounting the transducer in direct contact with the surface of the wood as used by previous investigators provides two distinct advantages. One: Wallboard or other coverings of areas that need to be inspected can be penetrated with the drill hole to allow access of the wave guide to the underlying wood structure. Two: Placing the wave guide internally with good mechanical coupling to the wood provides access to extensional stress waves, created by the in-plane termite activity source, traveling along the grain of the wood. It has been well established that attenuation of stress waves along the grain of the wood is much less that across the grain. This feature allows us to detect termite activity over twice the distance obtained by placing the transducer on the outer surface of the wood. After placing the probe in a drill hole, a curly telephone cord is used to connect it to the hand held instrument.

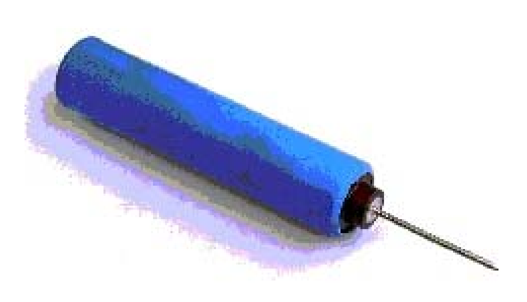


Figure 3

TERMITE TRACKER SYSTEM (Patent Pending)

Probe unit with replaceable Waveguide tip, PE sensor and Amplifier/Filter

Electronics unit with Nicad battery pack

Battery charger

4 conductor Phone phone cord with modular connectors

Figure 4

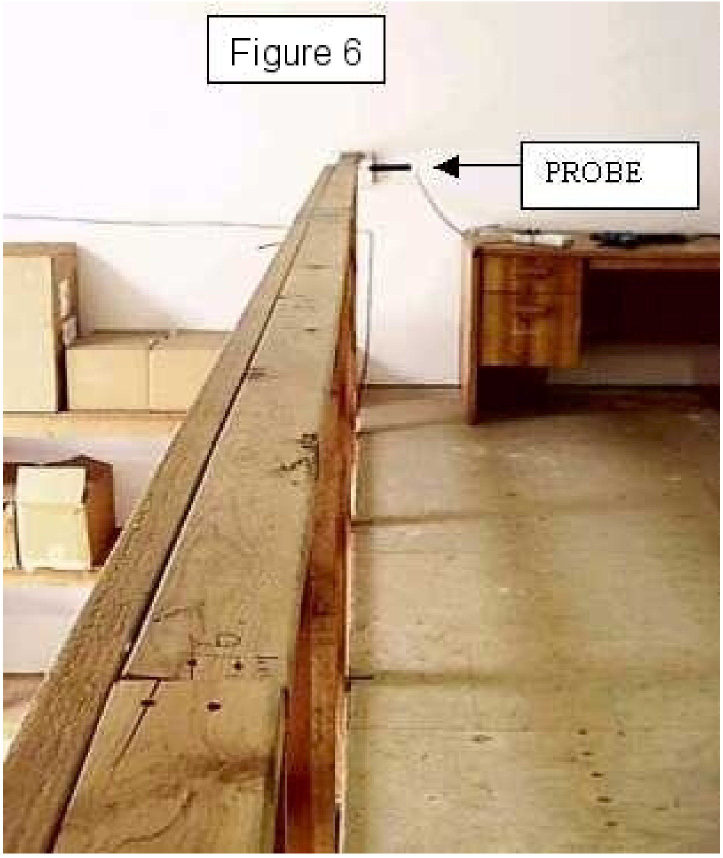
TERMITE TRACKER SYSTEM

Figure 4 shows the over all system used to gather the data used in this report. Figure 5 shows details of the instrument controls. The procedure for testing is first to drill a hole in the wood member to be tested approximately + inch deep, using a 0.125 inch diameter drill. The telephone cord connector in one end of the probe provides for easy connect and disconnect of the cable. With the cable disconnected the probe wave guide is screwed into the drilled hole until the point of the wave guide comes into contact with the wood at the bottom of the hole. In the lower left hand corner of figure 5 the time for taking data is selected (30 sec, 1 minute, 2 minute, 10 minute, 30 minute, and continuous). There are 5 sensitivity levels available; sensitive level 5 represents the highest sensitivity (0dB attenuation). Each of the other 4 levels represent a 5 dB attenuation of the signal. Therefore level 1 represents a 20dB attenuation of the signal. At this level feeding activity can be detected but movement of the termites cannot be detected.

TERMITE TRACKER (Patent Pending)
CONTROL IDENTIFICATION

Figure 5

The instrument is powered on by the audio volume knob and the instrument will immediately begin taking data for the time period selected. The signals detected by the instrument are rectified and envelope detected such that one count is displayed in the counts display for each event detected. A unique nonlinear circuit design provides the same volume audio signal regardless of its amplitude over the 20dB dynamic range selected.



ATTENUATION STUDIES

Attenuation studies were conducted on the 5 meter long fir 2” X 4” board shown in figure 6. The probe was screwed into a drill hole on the two inch side of the board at one end. Drill holes were then made in the 2 inch section at 1 meter spacing along the board to allow for pencil lead breaks to be made inside the holes to simulate the in-plane stress wave created by the movement of termites. These simulated tests were conducted at the 5 sensitivity positions available from the instrument.. Note from figure 6 that the instrument is laying on the desk 5 meters away from the intersection of the 5 meter board with another board in the foreground of figure 6. 0.3mm pencil leads broken in a drill hole of the long board at this intersection could easily be heard from the audio speaker in the instrument over 5 meters away.

Table 1 shows the results of this attenuation test. The 0.3mm pencil lead breaks were detected over the full 5 meter distance for sensitivity levels 4 and 5. At sensitivity level 3 the pencil leads were detected over a distance of 4 meters. At both sensitivity levels 1 and 2 the pencil leads could be detected over a distance of 3 meters. These results indicate that at the maximum sensitivity level of 5, the pencil leads should be detectable over a much longer board but we did not have one available to test.

TABLE 1

Detectability of 0.3mm pencil lead breaks at 5 different distances for 5 sensitivity levels.

DISTANCE ALONG BOARD FROM PROBE

Sensitivity	1 Meter	2 Meter	3 Meter	4 Meter	5 Meter
1	Yes	Yes	Yes	No	No
2	Yes	Yes	Yes	No	No
3	Yes	Yes	Yes	Yes	No
4	Yes	Yes	Yes	Yes	Yes
5	Yes	Yes	Yes	Yes	Yes

It has always been assumed by previous researchers that the attenuation of wood is so great that a continuous piece of wood without discontinuities, including mechanical fasteners would be necessary to satisfactorily detect termite activity. Since we are using a new approach utilizing a wave guide to detect in-plane stress waves along the grain of the wood we decided to perform some simple experiments to test the effectiveness of fasteners in coupling the energy from one piece of wood to another. Figure 7 shows the probe attachment at the end of the 5 meter board shown in figure 6. This board has been nailed to the upright 4 X 4 inch board approximately 1 meter long. Another 2 X 4 inch board is shown attached by only a hinge to the board containing the probe.

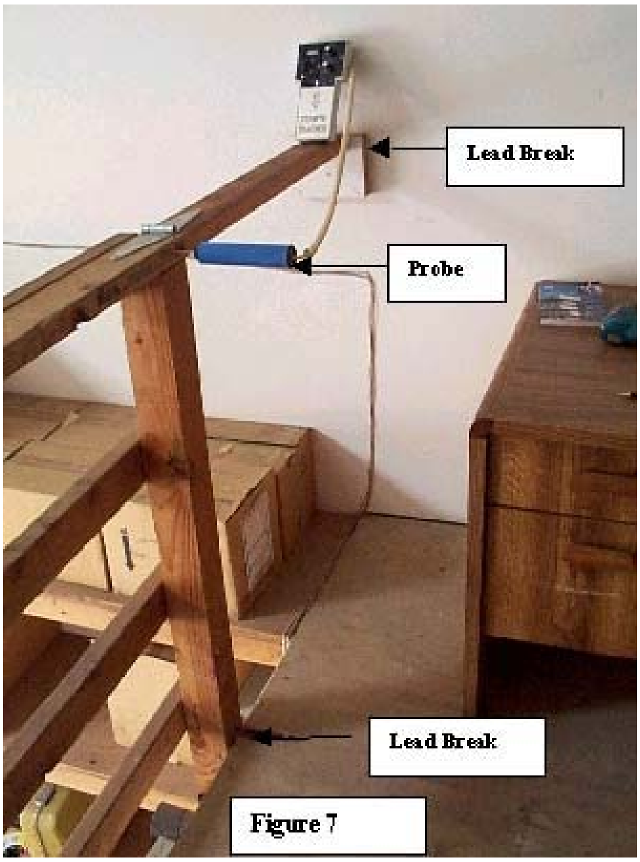


Figure 7

Sensitivity 1, the least sensitive position of the instrument was selected and 0.3mm pencil lead breaks were made at the positions shown in the figure. The lead breaks were detected by the instrument in both cases. Apparently the nails and hinge used to connect the individual pieces of wood were satisfactory in providing a path for the transmission of the stress waves from one piece of wood to the other.

TERMITE DETECTION

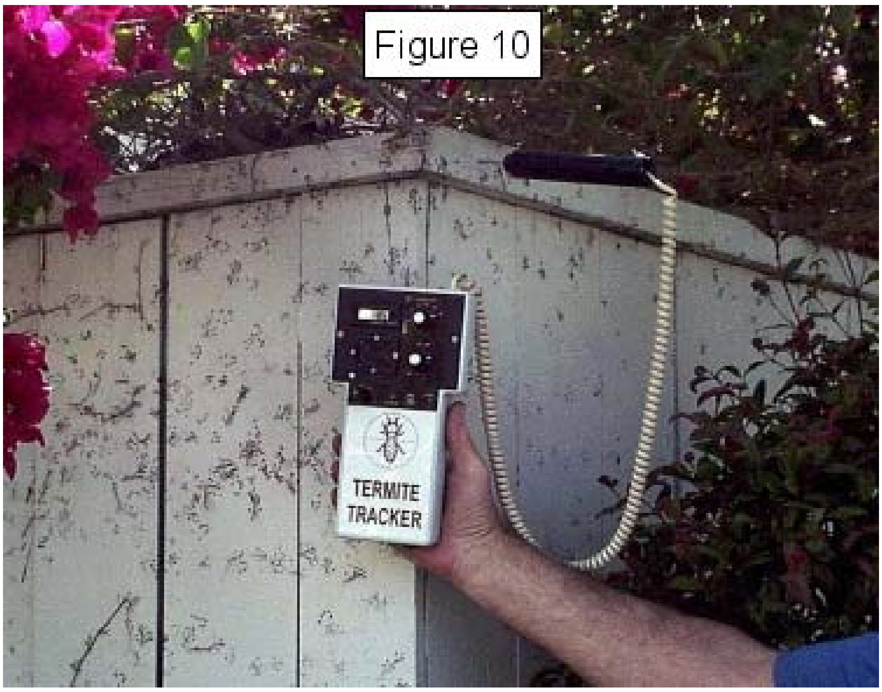
Approximately 6 months ago the author noticed droppings (sawdust) from termites on the fence enclosing the Patio of his home. It was difficult by visual observation at that time to tell which of the boards in the fence contained the termites. After completing the Termite Tracker instrument it was used to locate which of the boards in the fence contained termite activity. It was found that the top board of the fence was the only board which gave an indication of termite activity. Figure 8 is a photograph of the fence showing the top board which is infested with termites. Drill holes were made in the top board with spacing of approximately 1.5 meters. The probe of the termite tracker was inserted in each of the holes and the termite activity was recorded. We observed the highest activity near the end of the board which is located at the center-left in figure 8. It is interesting to note that obvious physical damage is present when observing the top of the board approximately 2 meters down the length of the board. It also was noticed in this same vicinity on the inside of the fence that termite droppings (sawdust) was present on one of the lower boards. This evidence is shown by figure 9.


Figure 8

Although figure 9 shows visual evidence of the presence of Termites and the rail at the top of the fence in this location shows physical deterioration, the termite activity in this location was less than the activity at the end of the fence which shows no visual evidence that termites are present.

It was observed in this damaged section of the top rail that 0.3mm pencil lead breaks at sensitivity 1, could only be detected over approximately 1.5 meters from the probe. Apparently highly damaged boards cause a great deal of attenuation of the stress waves.

The probe of the instrument was next placed at the end of the fence showing the greatest activity and the activity due to the termites was recorded for 5 different sensitivities. A photograph of this area is shown by figure 10. A drill hole was made in the board at right angles to the board containing the probe, at approximately 80mm from the corner. We discovered that termites were also present in this board. Further testing in this board at 1.5 meters from the corner showed lower activity. 0.3mm pencil lead breaks were made in this board at approximately 80 mm from the corner. We discovered that at the lowest sensitivity of the instrument the lead breaks could be detected around the corner. Since a distinct gap is present between the two boards it became obvious that the nails joining the two boards acted as a transmission path for the signals. This observation led to the following experiment: 50mm long self drilling deck screws were screwed into the board in the active region adjacent to the drill hole used for inserting the wave guide of the probe. The probe of the waveguide was removed from the drill hole and the point of the waveguide held by hand in contact with the head of the screw. The termite activity could still be easily recorded in this manner but it was difficult to hold the probe steady by hand without creating extraneous signals at the nailhead –waveguide interface.



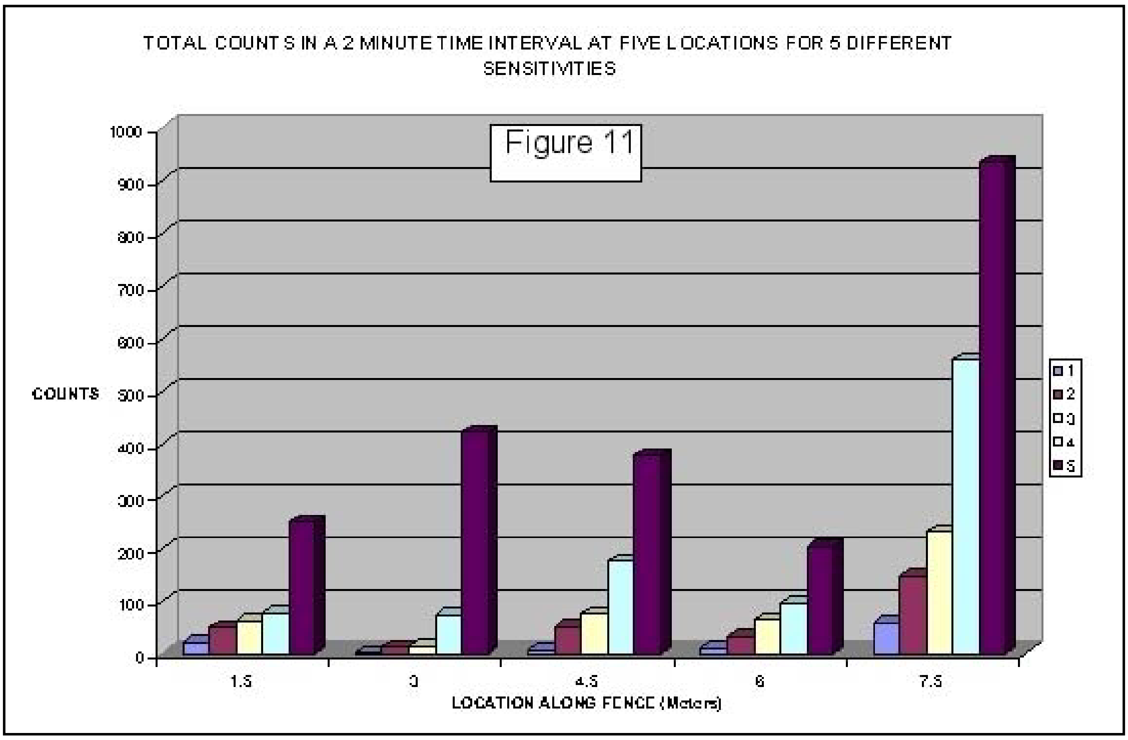


Figure 11

Figure 11 shows the results of the measurements made at five locations on the fence for five sensitivity levels of the instrument at each location.

The data in figure 11 was taken several hours after drilling the holes in the fence. We therefore believe that these measurements were made during normal feeding and movement of the termites within the gallery. Note that activity was recorded for all range levels of the instrument which shows that the dynamic amplitude range of normal termite activity covers at least 20dB. We believe that the signals detected at levels 1 and 2 and possibly 3 of the instrument are due to feeding of the termites, since this activity produces the highest amplitude signals. We believe that the signals detected at levels 4 and 5 are primarily from movement and other activity of the termites within the chamber. To test this hypothesis the following experiment was performed.

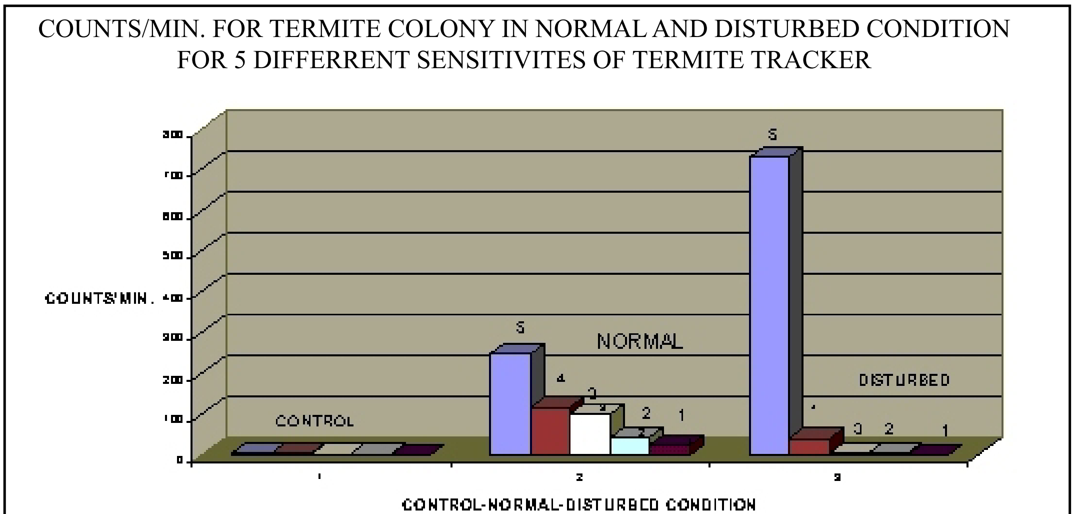


Figure 12

The probe was inserted into the drill hole at the 7.5 meter location. We then waited a couple of hours in order to relieve any disturbance created by inserting the probe before beginning to take data. One minute samples of activity were recorded at the 5 sensitivity levels. We then rapped on a deck screw that had been inserted into the board next to the probe with a hammer. This disturbance caused the activity at level 5 to increase threefold immediately. Zero activity was recorded on levels 1 and 2 and only a few counts/min were recorded from level 3. Figure 12 shows the results of this experiment. A background noise check was made for a 5 minute period previous to inserting the probe in the drill hole and no signals were detected. This is shown as Control in figure 12. The five levels of activity recorded in the undisturbed condition shows activity for all of the 5 levels of sensitivity of the instrument. Sensitivity 5 shows a threefold increase in activity following the disturbance, while very little data is shown for the 4 other levels.

COUNTS AT 30 SECOND INTERVALS FOLLOWING DISTURBANCE FROM AREA 5 OF FENCE AT SENSITIVITY LEVEL 5

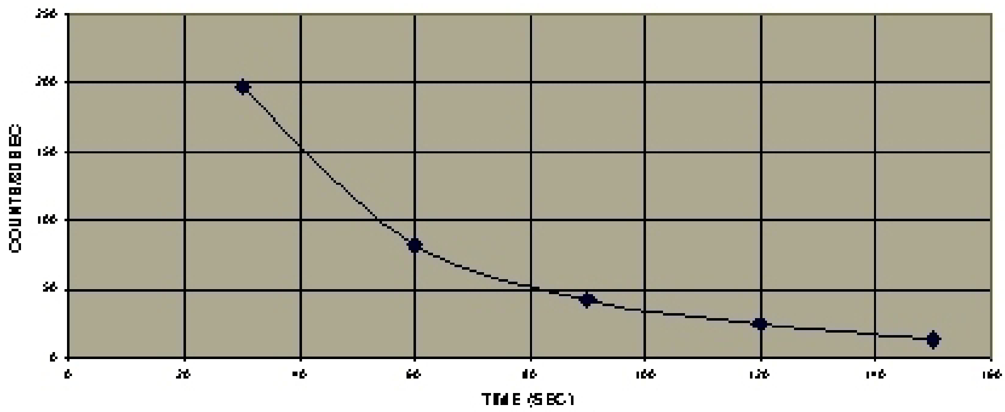


Figure 13

TERMITE ACTIVITIY AREAS FOR 5 DIFFERENT SENTITIVITIES

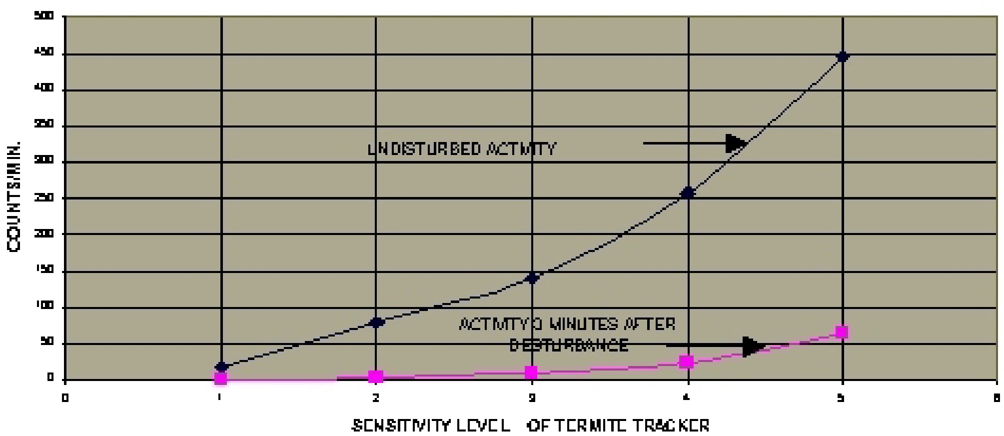


Figure 14

There was no activity recorded for levels 1 and 2 and only a few counts/min for level 3.

Our interpretation of these results is that when disturbed, the termites quit feeding and make a mass exodus out of the area of disturbance. We are detecting the movement and banging around of the termites at level 5 as they move out of the gallery. The lack of any high amplitude signals normally recorded at levels 1 and 2 demonstrate the lack of feeding during this process.

The next day this same experiment was repeated with the following modification. After disturbing the termites, the counts from level 5 were recorded at 30 second intervals for a period of three minutes. Figure 13 shows the results of this experiment. A modification of this experiment was repeated the next day at a different location in the fence. The normal undisturbed activity was recorded at five different sensitivity levels. The termites were then disturbed by banging on the fence with a hammer. We then waited 3 minutes and again recorded the activity from the same location at the five sensitivity levels. Figure 14 shows the results of this experiment. The very low level of activity even at the most sensitive level confirms the data in figure 13 that following a disturbance the termites leave the area and move on to somewhere else. The data in figure 13 shows our ability to detect this movement out of the gallery.

DISCUSSION OF RESULTS

ATTENUATION STUDIES

The attenuation studies shown in Table 1 demonstrate that the attenuation of stress waves along the grain of a dry undamaged fir 2 X 4 board is low enough to provide adequate sensitivity to the detection of Termites in a continuous wood board over a distance of several meters. Even at the lowest sensitivity of the Termite Tracker, 0.3mm in-plane pencil lead breaks were easily detected at a distance of 3 meters when using the wave guide. The transducer was removed from the probe and coupled directly to the side of the 2X4. The pencil lead breaks could only be detected at a distance of 1.5 meters distance with this type of coupling. Only at the maximum sensitivity of 5 could the pencil lead breaks be detected over the full 5 meter distance whereas at a sensitivity level of 4, use of the wave guide allowed detection of the pencil led break over the full 5 meter distance.

TERMITE ACTIVITY

Figure 11 is an Excel graphic showing the data recorded from Termite activity in the patio fence. Activity was recorded at all 5 locations and could be detected over the full 5 sensitivity ranges. The sensitivity position switch is an attenuator with level 5 representing the most sensitive position (0dB) with each of the other 4 levels representing a 5 dB attenuation of the signal. The data shown in figure 11 demonstrates that the dynamic range of amplitudes produced by the termite activity covers a range of at least 20dB. This large range of signal amplitudes is probably due to the orientation of the feeding and movement activity in respect to the quality of the adjacent wood where the activity is occurring, the size of the cavity, and the position within the cavity in respect to the probe location where the feeding and movement is occurring.

The Termite activity from the 7.5 m location in figure 11 was monitored several times over a period of one week under different temperature and atmospheric conditions. The highest activity (1000 counts/min, 76 degrees F) occurred on a warm and sunny day, the lowest activity (250 counts/min) , 62 degrees F) occurred on a colder day with wet fog. Both of these measurements were made at the highest sensitivity level 5. In both cases activity was still measurable at the lowest sensitivity level 1. The data taken at the least sensitivity (level 1) seems to correlate best with previous experiments of Scheffrahn and co-workers who reported only recording of feeding activity. (Reference 2).

The data in figure 11 was taken by carefully inserting the probe into holes drilled several days previous. A minimum of disturbance of the board containing the termites was our goal. We believe the data taken corresponds to normal feeding and other activity of the colony. The data shown in figure 12 following rapping on the board with a hammer is clear evidence that after being disturbed the termites quit feeding as evidenced by a lack of signals at levels 1 and 2, and proceed to quickly evacuate the disturbed area as evidenced by the large number of counts due to movement at sensitivity level 5.

We experienced occasional extraneous noise signals from traffic and other sources during the measurements of termite activity on the fence but this presented no problem in interpretation of the data since a few extraneous signals have little effect when we are recording hundreds of counts per minute on the most sensitive range. Extraneous noise has its greatest impact when only recording signals due to feeding at level 1 since only 10 or 20 counts/min are usually observed at this sensitivity level.

CONCLUSIONS

A new approach to Acoustic Emission detection of the movement of termites is presented. The new approach makes use of a metal waveguide and 40Khz transducer combination that can be inserted in a drill hole in order to measure the extensional stress waves produced by the movement of the termites. Previous instruments have only shown the ability to detect the high amplitude signals due to feeding activity. The high numbers of counts detected due to movement makes this instrument much more resistant to data contamination due to occasional extraneous noise signals. In addition the higher sensitivity provides detect ability over a larger area. The ability to record termite activity over 5 sensitive ranges provides a method of determining that normal undisturbed activity is occurring in a termite gallery by comparison of the relative activity on each level of sensitivity. If also provides a method of separating signals from feeding activity from those due to movement. The data shows that following disturbance the termites evacuate the area of the disturbance and almost all activity even at the most sensitive level ceases in a matter of a few minutes. Therefore if one wishes to record termite activity at a particular location it must be done quickly after, for instance drilling a hole in order to observe the movement activity before the termites leave the area. Figures 12 and 13 shows that if one is using an instrument sensitive only to feeding activity (level 1), the probability of detecting termites immediately after drilling a hole is small since feeding activity immediately ceases following the disturbance. Precautions should also be taken when applying treatment to eliminate the termites. If holes are drilled to inject insecticides or liquid nitrogen, the treatment should first start at either end of a given board and work toward the middle, otherwise the termites may travel to a location where there is no visual evidence of their presence and escape the treatment.

We have also shown that the waveguide-sensor combination, along with our low noise circuit design has resulted in an instrument for detecting termite activity that we believe is an order of magnitude more sensitive than any produced thus far. In addition to locating termite activity our approach of using the waveguide inserted into a drill hole or the use of deck screws as waveguides can prove useful in providing solid evidence that termite eradication procedures such as tenting or other treatment methods are effective in eliminating termites. The drill hole or deck screw properly marked can be tested prior to and after treatment to assure that the treatment was effective. To the authors knowledge there is no other method that can give immediate evidence that a treatment has been effective. This report only discusses detecting Termite movement. The new instrument should also be capable of detecting the movement of other types of wood boring and wood feeding insects.

REFERENCES

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2. Scheffahn, Rudolf H., William P. Robbins, Philip Busey, Nan-Yao Su, Rolf K. Mueller. Evaluation of a Novel Hand-Held Acoustic Emissions Detector To Monitor Termites. Journal of Entomological Society of America. December 1993.