ELIMINATION OF EXTRANEOUS NOISE SOURCES FROM ACOUSTIC EMISSION BASED TERMITE DETECTION INSTRUMENT BY USE OF MODAL RATIOS

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INTRODUCTION

The major problem faced with the use of "acoustic or acoustic emission" instruments for the detection of termites or other wood feeding insects in wood is their susceptibility to being triggered by extraneous air borne signals as well as friction between members or casual contact of the board being inspected. The primary reason extraneous noise is a problem results from the basic design of the instruments. It is desirable to detect the termite activity in wood products which are inherently attenuating in nature compared to other types of buildng materials such as metals and glass. Therefore it is necessary to operate in the frequency range from 30KHz to 150KHz with high amplification of the sensor signal in order to detect termite activity at a reasonable distance from the sensor in wood products.

This low frequency operation and high sensitivity needed to detect termites results in an instrument that is also very good at detecting signals that are airborne and signals due to impact and friction on the member being tested.

This problem is very similar to the problem faced when designing acoustic emission instrumentation for detecting crack growth in structures constructed from metal plates, such as aircraft and bridges. The solution we found for solving the problem of extraneous noise in these types of structures led to the issuance of several patents. The basis for these patents is the use of modal ratios of different plate modes traveling in the plate.

It was discovered that out-of-plane (OOP) sources of acoustic noise such as airborne, impact, and friction, resulted in a large low frequency flexure wave, a shear wave, and a small component of an extensional wave. A growing crack is an in-plane (IP) source and produces a high frequency extensional and shear wave and a low amplitude flexure wave whose amplitude depends on the depth in the plate where crack extension occurs. We discovered that breaking the detected signal into a high frequency (HF) component, and a low frequency (LF) component, and taking the ratio of the HF/LF amplitudes would allow us to identify the type of source (OOP or IP) that produced the signal. An instrument was designed to detect the peak amplitude of the HF and LF components and calculate their ratio. A filter was designed such that a set ratio value could be selected and only signals produceing ratios above the set value would be accepted as a crack growth created signal. The reader is advised to read the above patents for a detailed explanation of the modal ratio procedure.

TERMITE ACTIVITY

There exists a close parallel of detecting crack growth in metal plates and detecting termites in a wood plank. Both the crack growth and the termite activity are (IP) sources for generating stress waves which can be detected with acoustic emission sensors and instruments. There is also a close parallel in both cases that extraneous noise sources are (OOP) sources. Therefore an experimental study was made of termite activity using our instrument the AESMART 2000 developed under the previous named patents to determine if modal ratios could be used to eliminate extraneous noise for the portable TRACKER instrument. The results proved very successful and the modal ratio circuit with the appropriate filters will be incorporated into the portable TERMITE TRACKER instrument as well as a multiple channel instrument the AESMART TERMITE DETECTOR. Experimental results of this study will now be presented.

<u>EXPERIMENTAL PROCEDURE</u>

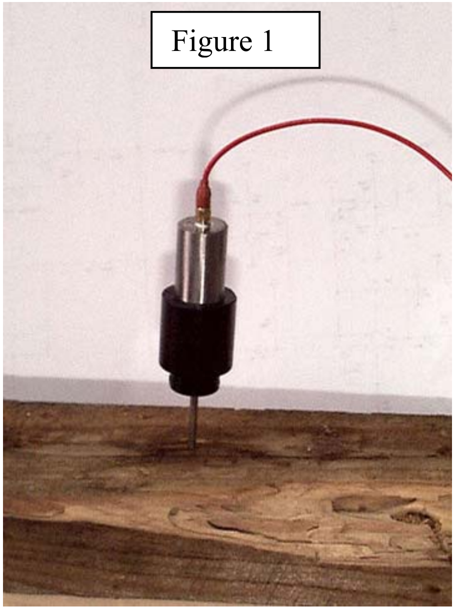


Figure 1

A wood board 2X4 inch in dimensions and 2 meters long containing termites was used in the study. Figure 1 shows the board with the TERMITE TRACKER transducer attached to a waveguide that has been inserted into a drill hole in the board.

Figure 2 shows the experimental setup used for detecting and recording the signals from the termites in the board. The instruments used were the AESMART 2000, a Tektronix digital oscilloscope with FFT capability, and a Krohn-hite band pass filter with 4 pole skirts.

The SE40-Q 40 KHz transducer seen attached to the waveguide in figure 1 was fitted with a 20dB internal preamplifier which was powered by the AESMART2000 instrument. The broadband signal 20KHz-500KHz from the AESMART 2000 was first inserted into the digital oscilloscope in figure 2 in order to measure the broadband frequency response of termite activity and extraneous noise sources. It was discovered that most of the termit activity and airborne and rubbing noise was contained in the frequency range from 20KHz to 50KHz.   This was not surprising since the peak response of the SE40-Q transducer is in the 40KHz range of frequency.

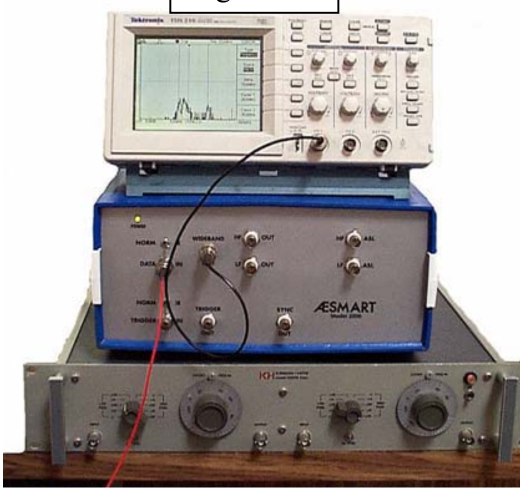


Figure 2

We discovered that the frequency spectra of the termite activity and the extraneous noise sources did differ significantly which led us to further experiment with the use of frequency ratios in order to develop a modal ratio filter.   This was accomplished by bypassing the filter stages in the AESMART 2000 instrument, and using the variable bandpass filter capability of the Krohn-hite instrument instead.

Figure 3 shows the frequency response of the termite activity averaged over 126 samples. Note that there appears to be two distinct frequencies bands from the termite activity containing most of the

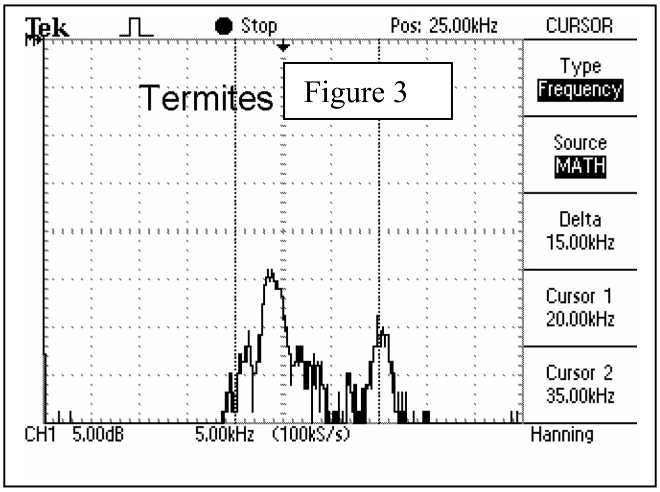


Figure 3

energy of the signals at approximately 25KHz and 35KHz frequencies. The lack of any signals below 20 KHz is due to the presence of a 20KHz hi-pass filter. Since the resonant frequency of the SE40-Q transducer is 40KHz we were surprised to see a lack of signal at this frequency. This is probably due to the modification of the frequency response caused by the waveguide attached to the transducer.

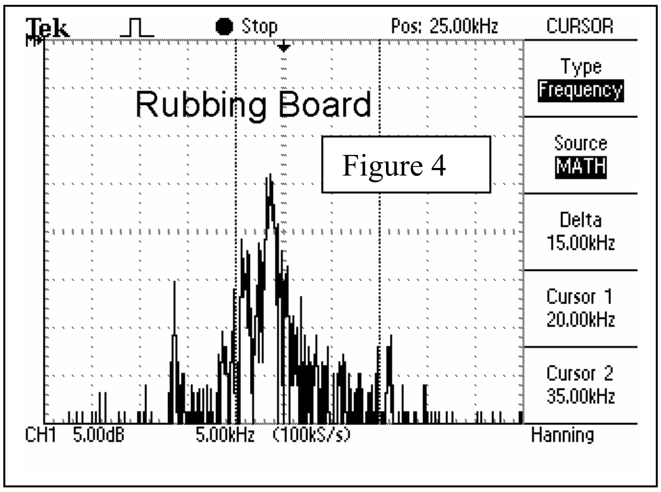


Figure 4

Figure 4 shows the frequency content averaged over 126 signals produced by gently rubbing the board with the index finger near the transducer location. This rubbing could also be detected at 1 meter away from the transducer. Note that the low frequency content of the signals matches that of the termite activity but there is a lack of signals at the higher frequency compared to the termite activity. Note also that the average amplitude of the low frequency signals are 10dB higher than that from the termite activity.

Figure 5 shows the frequency spectra produced by jingling of car keys 1 meter away from the transducer. Note a shift to lower frequencies in comparison to the termites and rubbing, and a lack of higher frequency content. Again the amplitude of the low frequency signals appear to be approximately 10dB higher than the amplitude produced by the termites. Jingling of the car keys at 30 feet distance from the transducer could still be easily detected by the system.

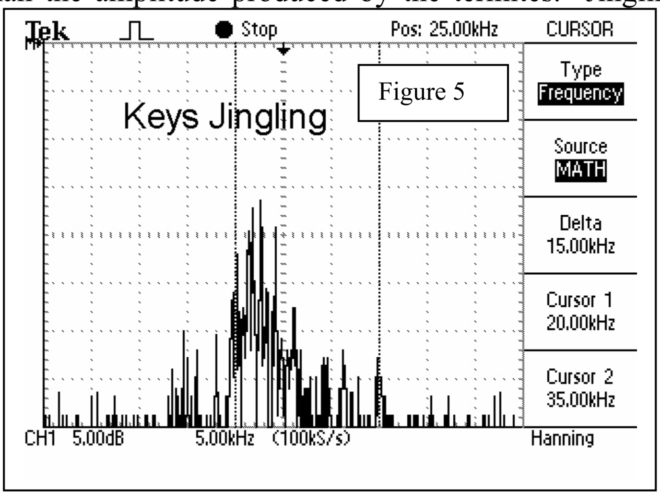


Figure 5

<u>FILTERING TECHNIQUES</u>

The high frequency and low frequency filters normally used in the AESMART 2000 were bypassed and the Krohn-hite variable filter instrument was used for filter selection. The optimum filter ranges for separating the termite activity from the extraneous noise sources was a low frequency (LF) bandpass between 20 and 25KHz, and a high frequency (HF) bandpass between 25 and 50KHz. Signals from the termites and noise in these two frequency ranges were peak detected and passed on to the A/D converter in a computer running with DECI-24 labview based software. The peak amplitudes of signals with these two frequency components were digitized and the ratio of the was calculated. When a valid signal was detected: the time of the event, the sum of the events, the peak amplitude of the HF and LF signal, and the HF/LF ratio were recorded and downloaded to a microsoft Excel spread sheet. Figure 6 shows the type of information recorded in the Excel spreadsheet.

Figure 6

Run time	minutes	events	HF amp	LF amp	ratio	
23.85	0.3975	[illegible]	[illegible]	83	3.59	Filter =2 Filter on Termites
23.9	0.398333	[illegible]	[illegible]	322	2.61	
24.01	0.400167	132	1519	576	2.64	
24.12	0.402	133	415	117	3.54	
24.17	0.402833	134	728	156	4.66	
24.34	0.405667	135	391	181	2.16	
24.45	0.4075	136	322	88	3.67	
24.61	0.410167	137	439	166	2.65	
24.67	0.411167	138	1133	425	2.67	
24.83	0.413833	139	298	127	2.35	
24.89	0.414833	140	288	98	2.95	
25.05	0.4175	141	425	137	3.11	
25.16	0.419333	142	532	225	2.37	
25.43	0.423833	143	322	142	2.28	
25.49	0.424833	144	791	322	2.45	
25.54	0.425667	145	640	635	1.01	Filter Off Keys Jingling
25.6	0.426667	146	5615	5327	1.05	
25.65	0.4275	147	6367	6055	1.05	
25.65	0.4275	148	5625	4902	1.15	
25.71	0.4285	149	6221	6030	1.03	
25.76	0.429333	150	3276	3940	0.83	
25.76	0.429333	151	1948	2427	0.8	
25.82	0.430333	152	454	322	1.41	

A portion of this data was recorded with a ratio filter setting of 2 and the filter was turned on. Therefore only signals producing HF/LF ratios of greater than 2 were accepted by the system. The filter was then turned off and noise due to jingling of keys was introduced. Note that the ratios calculated due to this noise source are all below the value of 2. Note also that the amplitude of the signals due to this noise source were much higher in amplitude. Jingling of keys and Rubbing of the surface both produced ratios of less than 2 and were not recorded with the ratio filter set at 2 and turned on..

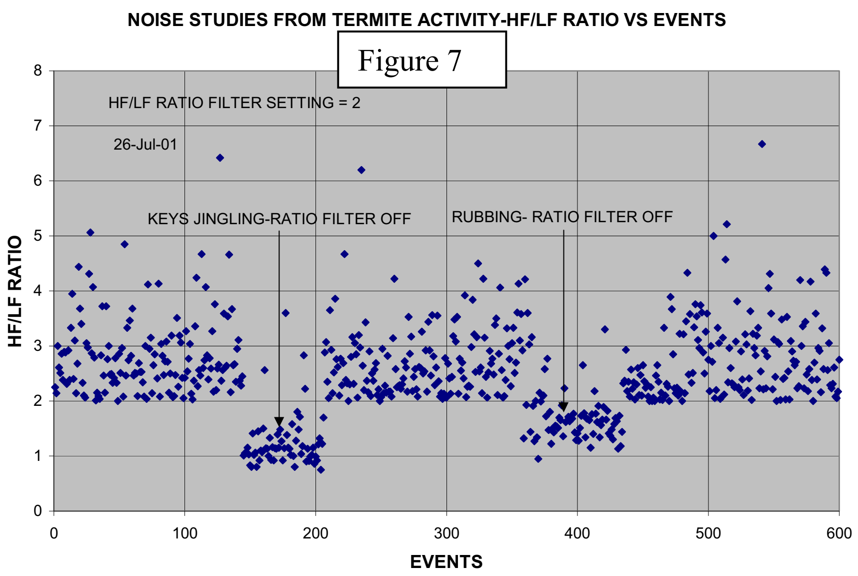
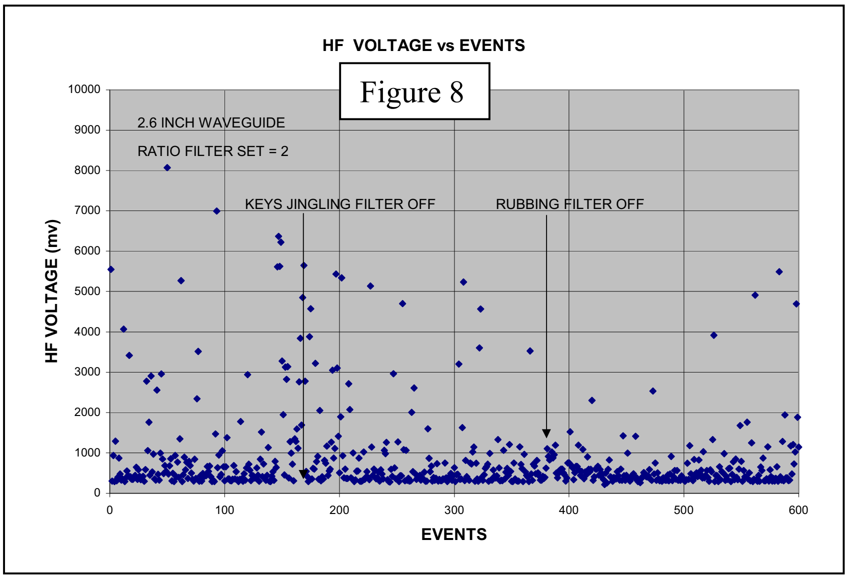


Figure 7

Figure 7 shows a graphical presentation of the calculated ratios as a function of events recorded during the test. Note that the ratio of the events recorded from the jingling keys and rubbing of the board while the filter was turned off, both group at values below 2. Both jingling of keys and rubbing of the surface produce a fairly constant noise source and therefore not much data from the termite activity is recorded during this period. Most noise sources encountered in the field only occur on a periodic basis. Therefore the loss of termite activity data during such a period is minimal.

Figure 8 shows a plot of the peak amplitude of the HF signals per event This data shows that over an order of magnitude range of amplitudes are present due to Termite activity.



The HF threshold for recording the data in figure 8 was set at 300 millivolts. We postulate that the signals above 1000 millivolts are probably due to feeding activity, and the numerous lower level signals due to movement and other activity within the gallery. Note that the signals recorded due to the keys jingling are higher amplitude than those due to termite activity as was shown earlier in this report. The noise signals due to rubbing do not show the same high amplitude difference.

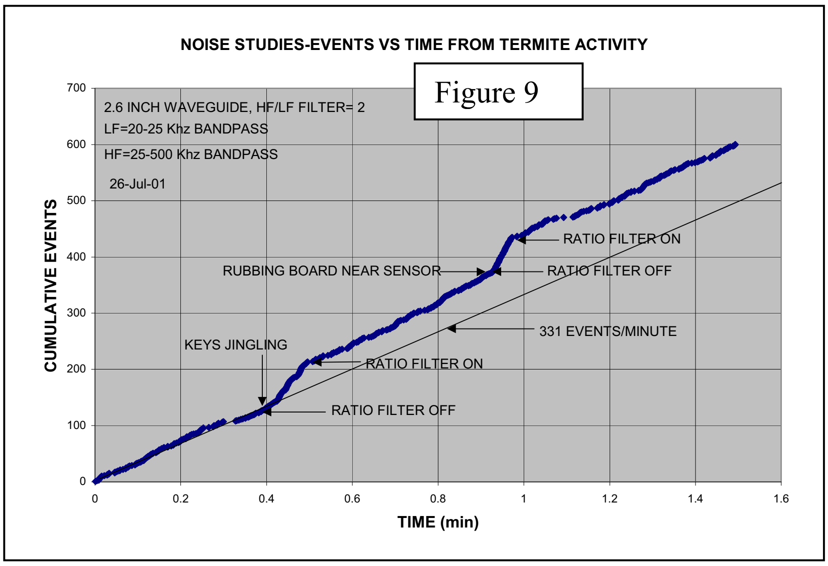


Figure 9 shows a graphic of the cumulative events as a function of time of the test. The average events per minute with the filter on, such that only termite activity is being recorded is 331 events/mnute. Note the increase in slope of the data for conditions where the filter is turned off and the noise sources due to jingling of keys and rubbing of the board produce signals that significantly change the event rate.

Termite activity can vary greatly over a period of 24 hours, but as can be seen by figure 9 the activity is fairly constant over a period of a few minutes.

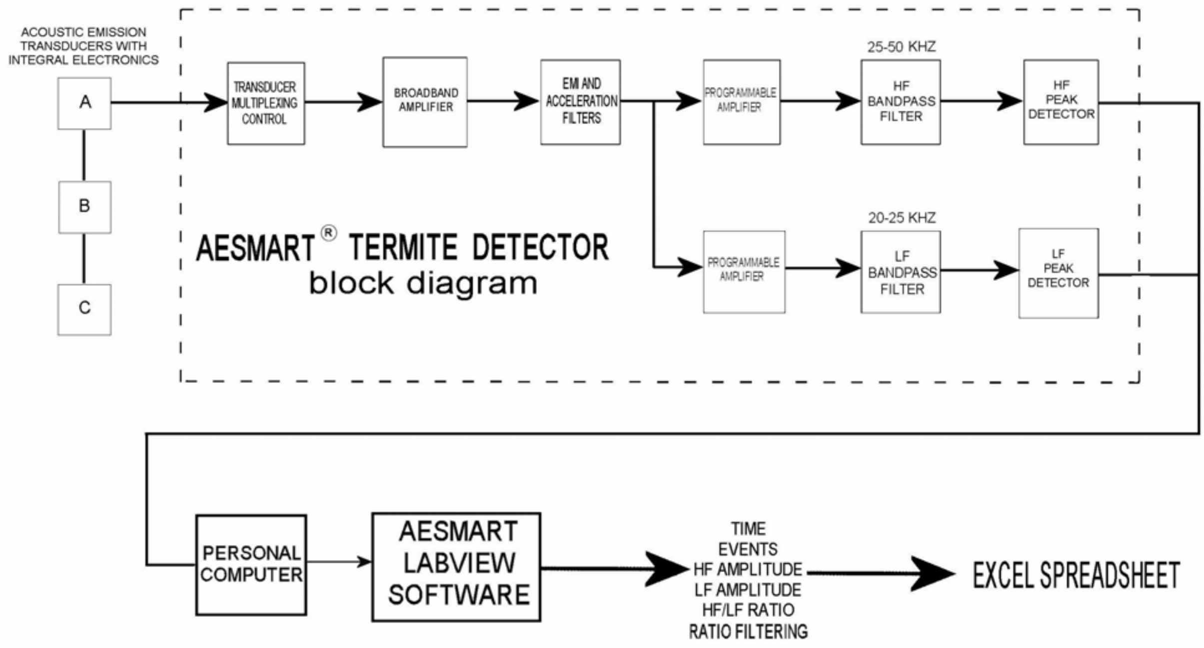
MULTIPLE CHANNEL OPERATION

An acoustic emission instrument that has the capability of filtering out extraneous noise sources such as impact, friction, and airborne signals will fulfill two primary needs: One, locating termite or other wood feeding insects where there is no visual evidence of their presence, and two, monitoring of treatment processes to eradicate such insects to assure that the treatment process has been effective.

For many situations involving local treatment, a portable battery powered unit can be effective in solving both of the above needs. In other situations involving tenting of large structures, which prohibit the presence of human occupancy. the ability to monitor many locations within the structure while the treatment is in process is desired. For this situation the multiplexing of many channels placed at stratigic locations throughout the structure would be an effective method to determine how long the treatment should take to eradicate the insects.

A simplified block diagram of such a system to accomplish the effective monitoring of many loacations is shown in figure 10. As many as 100 transducers in direct contact or mounted on

Figure 10



waveguides as shown in figure 1, could be placed in termite infested locations throughout a large structure. They could all be connected by a single cable, with each transducer having an address that could be selected by the computer for monitoring and recording of data from each specific location. The cable is then taken to a van or other vechile which contains the hardware and computer for analyzing the data. A dwell time is selected by the operator and the system sequentially "muxes" and records data from each channel based on the selected dwell time. The AE signal from the termite activity is split into two frequency components, the peak amplitude of each channel is measured and the ratio calculated by the computer. A ratio filter is constructed for the elimination of extraneous noise as shown by data in this report. The filtered data is downloaded to an excel spread sheet (figure 6) to allow analysis and plotting of each channels data.

The treatment process is started and all channels are monitored. When all channels cease to record any activity from the locations being monitored, the treatment can be considered effective in eradication of the wood feeding insects. If activity is recorded from any channel, the treatment process should continued until all activity ceases. Only then can it be determined that the treatment was successful.

In order for this monitoring method to be successful, the ability to measure movement of the insects within the gallery is necessary. Simply monitoring the higher amplitude signals due to feeding would not be adequate since the insects could simply quit eating but still be alive.