Technical Writing

Engineers and scientists perform many complex and intricate tasks using the world's most sophisticated equipment. However, their performance as engineers and scientists is almost always related to their use of one of the oldest tools - the pen. In academia, the saying "publish or perish" often describes the process of acquiring tenure as well as credibility. In industry, both large and small organizations communicate everything through memos, reports, and short presentations. Product development decisions are often made by a committee of people far removed from the actual technology. The saying "he who has the most convincing viewgraphs and reports, wins..." can sometimes apply to industry. Therefore, it should be clear that an ability to concisely and efficiently prepare technical reports, research papers, and or viewgraph presentations can have a profound positive impact on an individual's career. Consider the following statement by anonymous Fortune 500 corporate vice president:

> *"... in any large organization, the person who decides whether you get a promotion, or who determines the size of a pay raise, does not know you personally. The only thing they have to go on is what other people write about you and what you write about you ..."*

It can be seen that if one should write a lot of material to get ahead in one's career, it makes sense to write as objectively and concisely as possible. Objective writing is essential because good technical writing should not be seen as erroneous after new discoveries are made. A good technical report should present a clear milestone of what was done and understood at the time of the writing. Speculation about future research, or what might have gone wrong with the experiment or research, is acceptable so long as it is clearly labeled as speculation, rather than observation or fact. Objective reporting should be detailed enough to allow a technical peer to reproduce the experiment or research without difficulty. However, concise writing is also essential because everyone is short or time.

Every handbook on technical writing will emphasize the importance of knowing the audience to gauge the depth of details to present. It is also important to decide whether the report is for

teaching information, reviewing information, or presenting new technical results. As discussed below, the laboratory report style required for this course will minimize the amount of writing by focusing on the technical results of the experiments. However, a key skill to be developed is the ability to write abstracts and conclusions concisely and objectively. The abstract in particular will be stressed because it must summarize the entire work in a single short paragraph. An objective and concise technical report is a critical element in the process of technology development and dissemination.

Writing style for ACS 505

This course (ACS 505) will require a specific style of writing which will be helpful for quickly documenting research, preparing engineering reports and memos, and will provide the student some experience in technical writing on acoustics before preparation of his or her thesis. There are several style guides accepted by the University for thesis preparation where any one of them must be strictly and consistently adhered to. The style of the laboratory reports will be very simple to make student reporting as concise as possible. Only four sections will be allowed in this course: *Abstract, Procedure and Processing, Results and Questions, and Conclusions.* Emphasis will be placed on objective and concise writing in general, but especially for the abstract and conclusions. The procedure and processing section will be prepared by the student with only enough detail to allow an expert to reproduce the experiment(s), and will present all raw (unprocessed) data for the experiment in tables and/or graphs. The results and questions section will present the theory and techniques used to analyze the raw data in enough detail for an expert to reproduce the analysis in the report. If the lab handout has any specific questions to be answered, they should be done directly, by number in this section. The conclusions section should summarize the report and comment on the success of the techniques used, accuracy of the data, and improvements to the techniques for future experiments. The abstract should be written last after re-reading and editing the report. Abstracts are very important to scientific research and deserve careful attention by the author. The abstract should, in as few words as possible, summarize the techniques, results, conclusions, and accuracy of the experiment.

The tense of the laboratory reports shall be **third person present to refer to the current work in the report**, third person past to refer to previously published research, and third person future to refer to future research. Most technical information which makes it way across international borders does so via translation. Writing in a third person voice may sound a bit awkward or formal but, it often simplifies translation into other languages. In addition, a present tense in reference to the work of the report clearly distinguishes it from previous publications and future work yet to be done. Even though the work may have taken place a week or more before the writing of the report, its time with respect to the reader of the report should be the present. For example, the statement "... we computed a Fourier transform of the data and plotted the frequency response in Figure 3..." should be re-written as "... a Fourier transform of the data is computed and the frequency response is seen in Figure 3..." It may take some time to develop concise writing patterns to explain the technology of the experiment in the present, but it will make translation easier while discouraging "conversational" technical writing which is often imprecise and superfluous.

Technical reports should be as concise and objective as possible while also being complete to the point where an expert can reproduce the results from the report itself and, a novice can eventually

do the same after researching the referenced literature in the report. Laboratory reports are not ment to be textbooks and therefore should not attempt to teach or derive theory which is generally available in the open literature. One should simply state which technique(s) are used and reference literature where the reader can find all the appropriate details. In some cases, unreferenced derivation will be necessary in the report due to the uniqueness of the techniques and/or apparatus used. The style for theoretical derivation in the Laboratory reports will be numbered equations which are explained by the surrounding text. If many steps are required for a clear explanation, the derivation may be moved to a brief appendix at the end of the report where only the final result is included in the main part of the report with reference to the appendix. Proper use of references, tables, equations, and appendices saves the reader (and the author) a great deal of time and makes the report much more exciting to read (and write) by focusing on the subject at hand.

Hand-written laboratory reports are acceptable for this course so long as they are neat and the writing is legible. Skills using word-processors and computer graphics are obviously useful but will not result in higher grades for this course. The most important factors in the report are content and organization. All data presented in the report should be calibrated unless otherwise requested in the statement of work for the particular experiment. The report must conform without exception to this style guide, respond to every point in the statement of work for the experiment, and demonstrate the student's understanding of the technique(s) and results.

The Abstract

The abstract is the most-often read, and therefore the most important part of the laboratory report. It can be seen as an advertisement to entice the reader to spend some time examining the report's contents. Good abstracts can be very difficult to write before the report is completed. It is therefore recommended that it be written last as a summary of the salient points of the report. The abstract for the laboratory report should be a single paragraph 5 to 10 sentences long containing the following pieces of information:

- An explanation of what the experiment is
- A description of the techniques used
- The results of the experiment and their meaning
- A statement of how well the experiment worked and what future experiments might be needed for improved results

An example of a reasonable abstract for a hypothetical experiment on spectral analysis of speech can be seen below.

Example Abstract:

Both voiced an unvoiced connected speech waveforms are are analyzed in the frequency domain for purposes of identification of individual speakers. Sonograms are created using the

short-time Fourier transform as well as the wavelet transform to compare connected speech samples from four speakers by visual inspection. The wavelet transform, with its long integration time for low frequencies and shorter integration time for higher frequencies, produces sonograms which very effectively distinguish between the various components of the connected speech waveforms. However,for purposes of speaker identification, both the short-time Fourier transform and the wavelet transform appear to perform equally well. The data also shows that some speech samples are more effective than others for distinguishing individual speakers. More research is needed to determine standard speech samples and to develop objective tests for evaluating the utilities of the two transforms for use in speaker identification.

Note how only 6 sentences were needed to address the four main points above for writing an abstract. The reader can tell what was done and why, what techniques were used, how well they worked, and what new work is needed to move the technology ahead. The more potent or direct an abstract is, the better it will convey the highlights of the work and the reporting skills of the author. Like a good poet or jazz soloist it is best to "say what you have to say and get out". Note how the removal of any one of the sentences in the example abstract above significantly impacts in a negative way one or more of the four points for writing an abstract. It is also very desirable (if possible) to clearly state the limitations of the work so as to not mislead the reader into thinking the report is something beyond its actual contents.

The Procedure and Processing Section

For each experiment the student will receive a written description of the theory and experimental techniques, supported by one or more lectures, and a "statement of work" to be followed in order to perform all the tasks necessary. The statement of work must be followed precisely, step-by-step, in the procedure section of the laboratory report. However, all steps involving processing data (such as computing spectra), will be left for the results section. When encountering a "processing step", refer the reader ahead to the appropriate part of the results section where the processed data is presented. This style of reporting will leave all of the original data collected in the experiment in one place with clear identification as raw data. Simple measurements such as voltages, dimensions, mass, etc., should be organized into tables with an identifying number or letter, and referred to by the surrounding text. Hand-drawn tables, sketches of apparatus, or plots of data are acceptable provided they are neat and legible. Data recordings should be displayed graphically and "screen dumps" or other computer-generated graph outputs are generally acceptable. <u>All data should be presented in calibrated format including a calibration constant derivation unless it is specifically stated otherwise in the statement of work.</u> Calibration techniques will be a significant portion of this course. All steps in the procedure section will be concisely stated with enough detail for an expert to reproduce the data using only the laboratory report as a guide. The data in this section may be used by (or borrowed from), other lab groups whose experiment failed. Any data-swapping which occurs will be noted in the lab reports.

The Results and Questions Section

In this section, theory and analysis of the data is applied to meet the objective of the experiment. Theory and "the real world" usually don't agree perfectly because one always must deal with human error, imprecise tools, noise, and accidents. How one deals with all these formidable problems is to improve one's experimental technique, define the limitations and accuracy of the experiment, and when an accident occurs, report it honestly and clearly. When things do not appear to make sense or agree with theory, it is best that the author directly state so along with the reasons why as part of the conclusions section. And, if the analysis in the results section reveals an error in executing the procedure or an accident during the data collection it is very important to define exactly what went wrong and what must be done to correct it in the future as part of the reports conclusions. The student should make a reasonable attempt to obtain good data and an error-free analysis. However, one of the things which makes experimental work challenging and rewarding is an individual's ability to see through all the noise, errors, and imprecision to find the physics at work as defined by the theoretical models! This is an acquired skill which comes with experience, hard careful work, patience, and training. Experiments in acoustics and vibrations can be difficult and new improved measurement and analysis techniques are always in high demand.

The procedure results section must be concise while presenting enough detail for an expert to reproduce every step of the analysis using only the report. This could be to check the results or to try the analysis using a different data set. It will be necessary to state and reference the mathematical processes applied to the data if references exist, or to present the appropriate equations which would allow reproduction of the subsequent analysis. Equations should be either part of a table (such as a column title), numbered and referred to in the surrounding text, or part of a referenced appendix at the end of the report. As in the procedure section, processed data should be in either tables or graphs which are properly calibrated and labeled.

The Conclusions Section

Experiments are done for the purpose of confirming or disproving a hypothesis based on existing theory by means of a technique or apparatus. It can be seen that the object of each of the seven experiments which are part of this course is *to evaluate the use of the particular technique(s)* to observe the underlying physical theory. The conclusions section is where this evaluation is to take place. Explanation of data inconsistencies, known errors, and/or possibilities for future experiments which may improve the technique(s) should be discussed concisely and objectively. Any speculation by the report author must be clearly identified as such. The most important factor to be considered when preparing an objective conclusions is for the report author to offer insight into how the experiment might be improved without stating things unsupported by evidence. Consider this excerpt from Rayleigh's book (published from his lab notes and often written very informally) on the loudness variation with distance of two sound sources, an organ pipe and a tuning fork, of the same frequency and amplitude:

> *"... the two tones of pitch 128, one the difference tone and the other derived from the fork, were of equal strength as they reached the observer; but as the ear was withdrawn so as to emfeeble [weaken]*

both sounds by distance, it seemed that the combination-tone fell off more quickly than the ordinary tone from the fork. It might be possible to execute an experiment of this kind which should prove decisively whether the combination-tone is really an effect of the second order, or not."

- Lord Rayleigh, The Theory of Sound Vol II, (New York: Dover, 1945), p461.

This century-old passage is an excellent example objective reporting of an unexpected result and suggesting future work without unsubstantiated claims or assertions. What Rayleigh was unknowingly observing was an acoustic nearfield component which weakens exponentially, rather than inversely, with distance. At the time, this was not generally accepted or understood. The experiment the passage refers to was for determining the ear's perception of beat frequencies of organ pipes. Because the passage is objective and offers great insight into the results of the experiment, it is of great value even today. Technology and science are advancing at an incredible pace today as compared to Rayleigh's day. Many unexpected and even unexplained things occur during experiments and must be reported objectively. One cannot know what use these observations and/or suggestions for future experiments may have. If something unexpected occurs during an experiment, it is commendable to objectively report it along with suggestions on what to do about it next time. However, if one uses conjecture to explain experimental results, the reader will likely become frustrated substantiating the finding, call into question the scientific validity of the entire report, and put the report author into one of two categories: prophet or lunatic! Reports will be penalized heavily for conjecture and rewarded for insightful suggestions for improvements in future experiments. All finding of the report must be substantiated by either data within the report or referenced material available in the open literature.

Avoid Unnecessary Detail

One of the most common writing problems seen in this course over the past few years is unnecessary detail, derivations, and unlabeled speculation of results. It is tempting for some people to write a complete thesis showing every minute detail of some experiments which they may find really interesting. For example, explaining which buttons were pushed on certain equipment or simply repeating the statement of work for the lab in the same detail. The lab instructions and statement of work are given in detail to save time and insure specific measurements are made with the given equipment. However, much of this detail is useless to someone reading the report or trying to reproduce the experiment with different equipment. The reports should be written at an expert level which requires that the essential details of the procedure and results be mentally assimilated and summarized in the report. Tables should be used as often as possible to summarize the work done. It will be a challenge to make each report as concise as possible without losing the essential details which make the experiment reproducible.

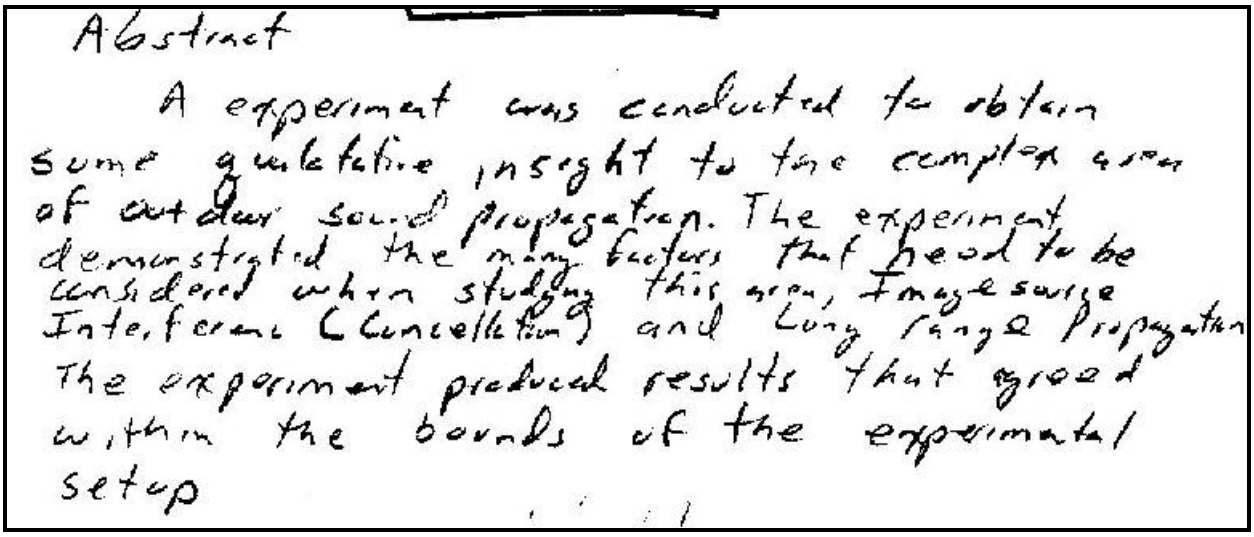
Examples Good and Poor Abstracts and Conclusions

Abstract A

In this experiment, source coupling and directivity are measured by starting with calibrations of the sources. From source coupling, the soundpressure level at a certain distance and angle with respect to separation/wavelength is measured. It is shown that at a separation of 5mm, the in-phase set has much higher sound pressure level than the one with reversed polarity (79dB & 33dB respectively), while as separation goes to 1mm, the pressure for the in-phase set drops down by about 12dB and the latter increases by about IOdB. It is explained that the total energy in this system doesn't change but that the portion that is dissipated through radiation is dmiinished. The directivity pattern for Radio Shack microphone is measured with results much the same as what is expected that sound pressure level between 0 and +,- 90 degrees increases as frequency goes higher and directivity patterns get more distinct although there is a little irregularity and asymmetry.

Abstract A is concise, accurate, and states techniques used and results.

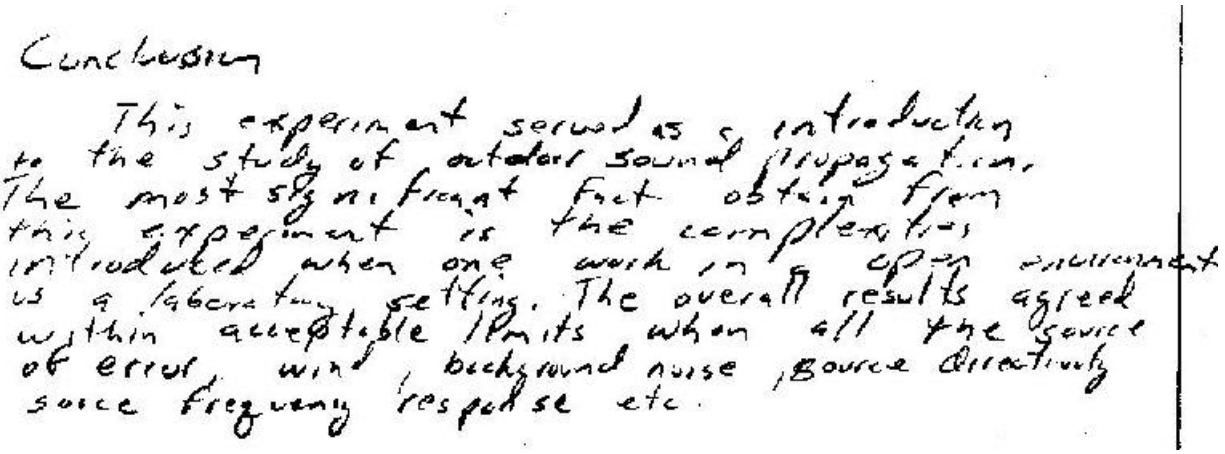
Abstract B


Abstract

A experiment was conducted to obtain some qualitative insight to the complex area of outdoor sound propagation. The experiment demonstrated the many factors that need to be considered when studying this area, Image source Interference (Cancellation) and Long range Propagation The experiment produced results that agreed within the bounds of the experimental setup

Abstract B is very weak. What was done?. What techniques were used? What does "within the bounds" mean?

Conclusion C


Conclusion

This experiment served as an introduction to the study of outdoor sound propagation. The most significant fact obtain from this experiment is the complexities introduced when one work in an open environment as a laboratory setting. The overall results agreed within acceptable limits when all the source of error, wind, background noise, source directivity source frequency response etc.

Conclusion C is very weak. Much more detail into how things worked is required.

Conclusion D

The experiment is successful in demonstrating source coupling and the directivity patterns of the piston source. The coupling of the two simulated point sources at the end of a duct out-of-phase showed a decrease in power, and thus the effects of active noise control. In comparing the power levels calculated by the analyzer between sinusoidal sources and a broadband source, the approximation using the number point FFT did not seem to make the two values comparable. In the future, if the measurements are all taken in linear or log scale, comparisons may be more effective. The directivity plots showed very well the changed in the piston source directivity at different frequencies. The comparison of the sinusoidal sources and the white noise source differed by about 5%. Overall the comparison between white noise source and the sinusoidal sources was not very precise, which may be due to some of the energy of particular frequencies leaking into other frequency bins during FFt averaging. However, the main theory of source coupling and directivity patterns are observed.

Conclusion D is excellent.