

DSPCommsJA

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Submission date: 03-Nov-2023 02:57PM (UTC+0000)

Submission ID: 214721874

File name: 32752_Joshua_Azare_DSPCommsJA_529633_856333451.docx (379.87K)

Word count: 1489

Character count: 7395

BEng Embedded
Electronic Systems
Digital Signal Processing
& Comms ACDA5008
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Abstract

Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Quad Phase Shift Keying (QPSK) exhibit different types of noise immunity at varying levels of noise in a channel. Running simulations in MATLAB Simulink with a Signal-to-Noise-Ratio (SNR) of +50dB to -30dB to represent ASK, FSK and QPSK modulators and demodulators, QPSK ran to -15dB before the Bit Error Rate increased. Errors in ASK started at -13dB and FSK saw errors the earliest at just -7dB, while also seeing the highest error rate at -30dB. ASK reached a BER of ~0.3 from -30 to -22dB. Overall, FSK is assessed to have performed the worst and be most susceptible to noise. QPSK is preferable in lower noise environments, as it can transmit at twice the rate of ASK or FSK. ASK performed similarly to QPSK once noise had been introduced into the system and had a sharper increase in error rate with each reduction in signal to noise ratio.

Introduction

ASK, FSK and QPSK are three options for modulating digital signals, that will be sent through a channel vulnerable to noise and interference from the surrounding environment, that are able to provide some noise immunity. The factors that this depends on are: The carrier and message wave amplitudes; The amplitude of channel noise. Together these combine to generate a SNR. The simulations run in MATLAB will be contrasting how different shift keying performs with differing SNR's in the channel.

Misplaced apos.

Amplitude Shift Keying

ASK is a shift keying technique where a sine carrier wave is multiplied by the message wave, consisting of digital 0s or 1s. This results in no signal being transmitted when a 0 is present in the message wave, and the sine carrier wave being transmitted when a 1 is present in the message wave. This is shown below in Figure 1 displaying a transition from a 0, to a 1, and back to a 0.

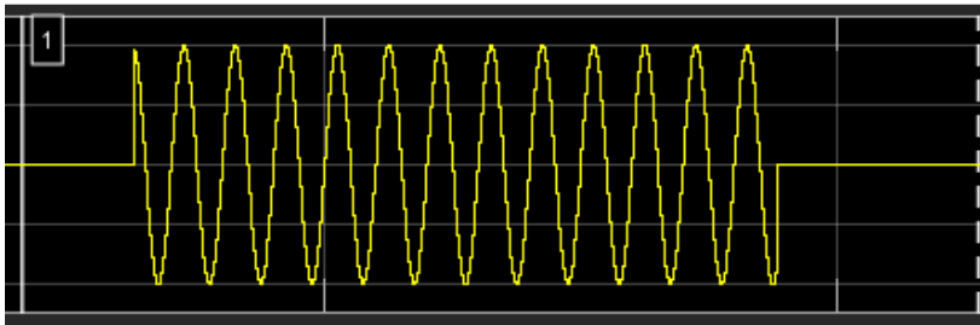


Figure 1: Amplitude Shift Key Modulation viewed on a Scope in Simulink

Demodulating the signal is similar to the modulation process: The signal is multiplied by the carrier wave (often referred to as a local oscillator). The upper image in Figure 2 demonstrates this below. This can be fed into a low pass filter, as the carrier frequency is of a higher frequency that needs to be discarded. The lower image in Figure 2 below shows the signal after a low pass filter is applied to it. A delay is visible in the line which is explained in the next section.

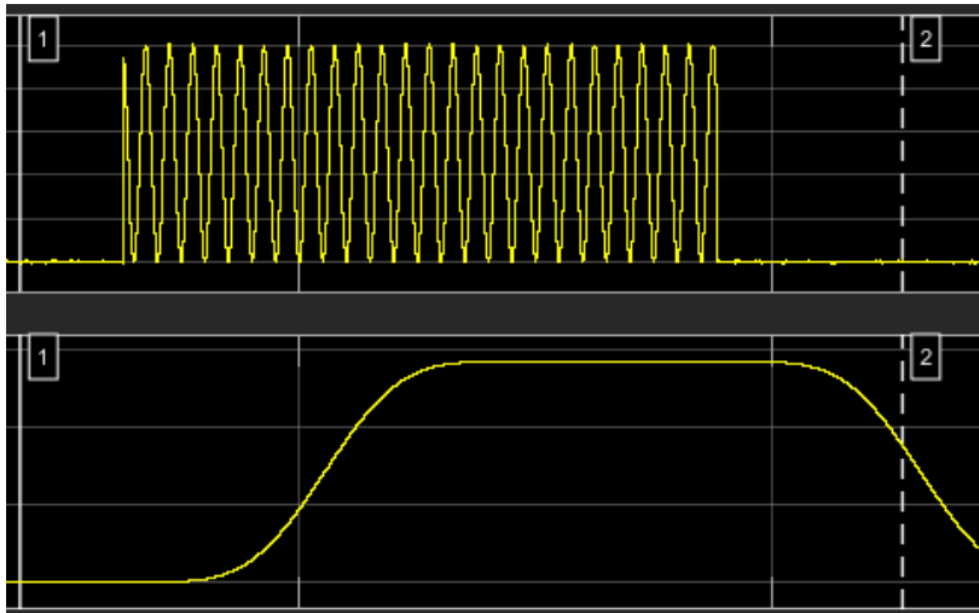


Figure 2: Amplitude Shift Key Demodulation and filtering viewed on a scope in Simulink

An advantage of ASK in analogue audio system is multiple messages may be broadcast at the same time, on the same frequency and the combined amplitude will be output from the demodulator. This is useful in a case where person A is transmitting on a frequency, but not speaking, and person B is speaking. However, for digital systems, this advantage cannot be realised as each time period has 2 possible discrete values.

Frequency Shift Keying

FSK is a shift keying technique that modulates the frequency of the message instead of the amplitude, as ASK does. The message wave selects between two different frequencies corresponding to a 1 or a 0, based on the inputs to a node that switches between the two. An example of this is displayed below in Figure 3.

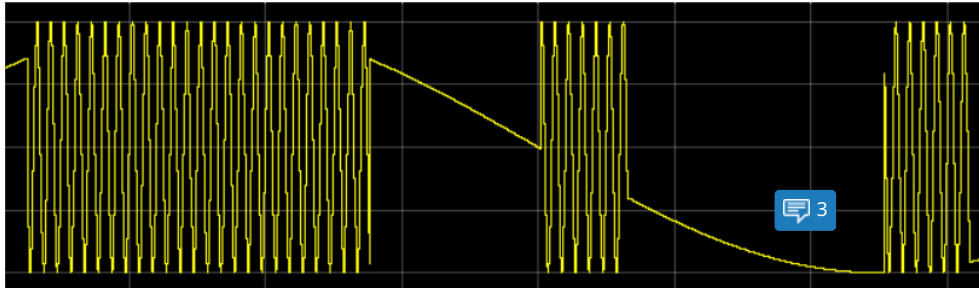


Figure 3: Frequency Shift Key Modulation viewed on a Scope in Simulink

The example above shows the much lower frequency message wave compared to the high frequency carrier wave.

Quad Phase Shift Keying

QPSK utilises neither frequency nor amplitude to modulate its carrier message. Instead, the phase is changed and for once, two bits of data may be transmitted at the same time.

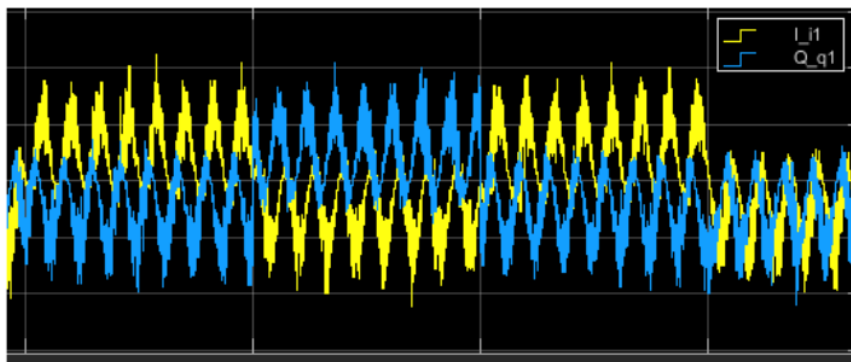


Figure 4: Quad Phase Shift Key I and Q components

Figure 4 above shows the I (in phase) and Q (quadrature) – out of phase by $\pi / 2$ radians, components of phase shift keying. By adding a negative phase to each, a total of 4 symbols can be represented by one resultant wave, shown below in Figure 5.

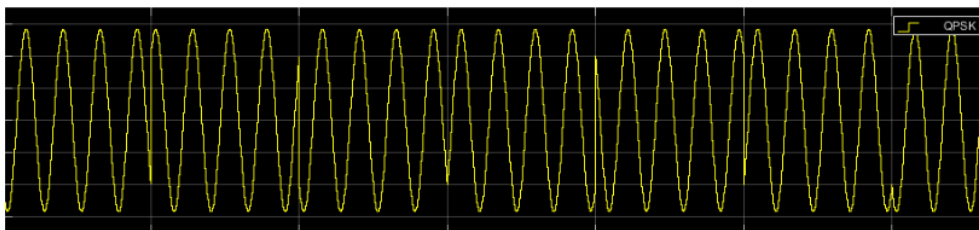


Figure 5: QPSK wave viewed on a MATLAB Simulink Scope

Simulation Models

A total of 35 values for the signal to noise ratio were used in all simulations, detailed in Annex 1. Each run was run a total of 7 times so that a mean could be taken and plotted to a graph.

The message frequency set for ASK and FSK simulations is $2 * \pi / 10$. For the QPSK simulation, the was set 1 due to filter errors. The carrier frequency set for ASK, FSK and QPSK simulations is $2 * \pi * 10$. This makes the ratio of carrier frequency 100 times the source data rate for the ASK and FSK simulations.

Filter design

The filter design uses a pass band of 1Hz and stop band 4Hz, with amplitude pass and stop bands of 1 and 80 respectively. The amplitude stop band of 80 contributes to a significant reduction in amplitude of noise that the signal wave picks up in the channel, however this has the effect of increasing the number of samples required to perform the filtering operation, adding a delay between the time the signal is received, and processed.

Processing time are limiting factors in real world applications of modulation techniques that uses a shift key. Increasing a filter to a high order may result in much better immunity to noise, but in doing so a very long delay can be introduced into the system. For systems transmitting audio, a 100ms filtering delay for example, would not have a significant impact on the user. However, in a safety critical system, low latency is paramount and considerations must be taken to reduce filtering delays.

This results in an 820-order filter, adding a delay of approximately 411ms to the receiving line. The initial delay is equivalent to 65% of the source data rate. The first symbol transmitted (with a 411ms delay added) and received arrive at the Bit Error Rate (BER) calculation block at the same time as cursors in the Simulink scope displayed the difference in time between transmit and receive lines.

Below are screenshots showing the MATLAB Simulink model for each of the simulations.

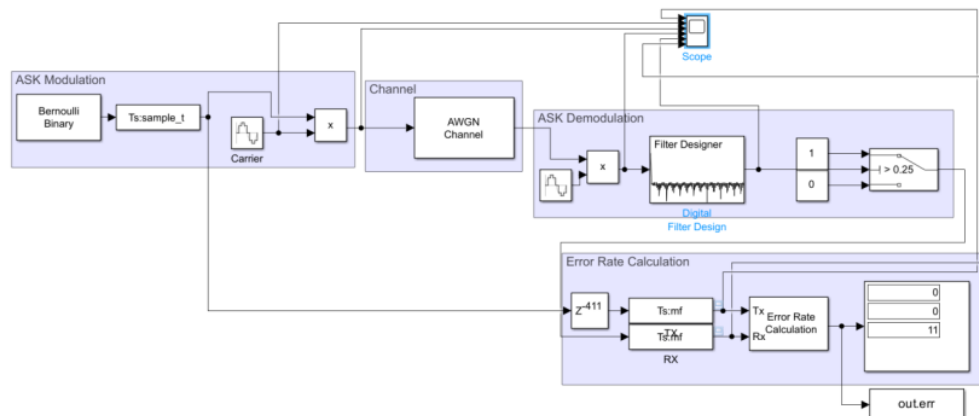


Figure 6: ASK Simulink Model

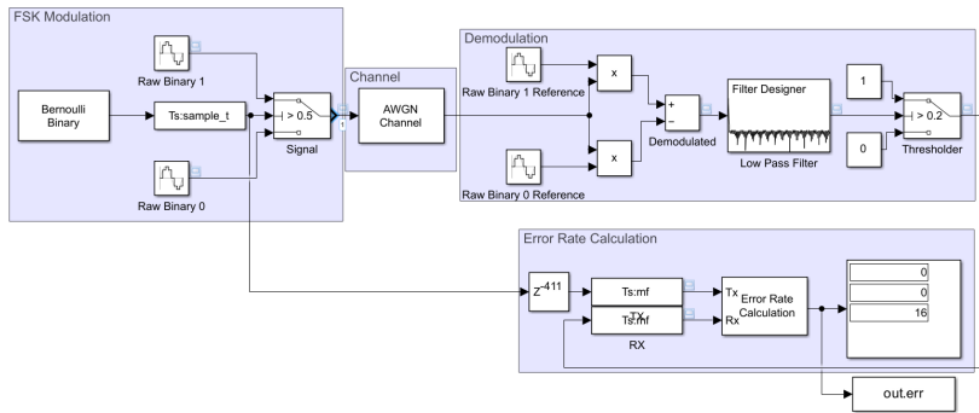


Figure 7: FSK Simulink Model

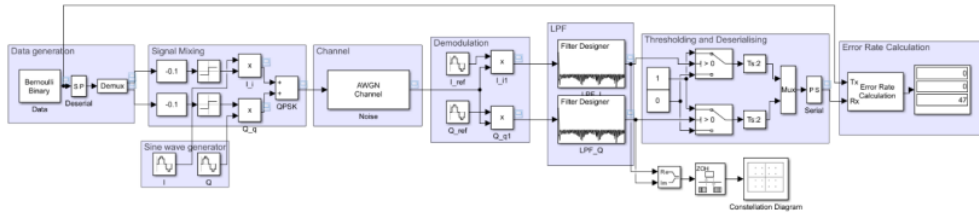


Figure 8: QPSK Simulink Model

For each of the models, the error rate calculator output was saved at the end to a MATLAB workspace, ran by a script listed in Annex 2. This allowed for a total of 245 runs to be performed for each model, producing a sufficient volume of data to be plotted, as displayed in the results section below.

Results

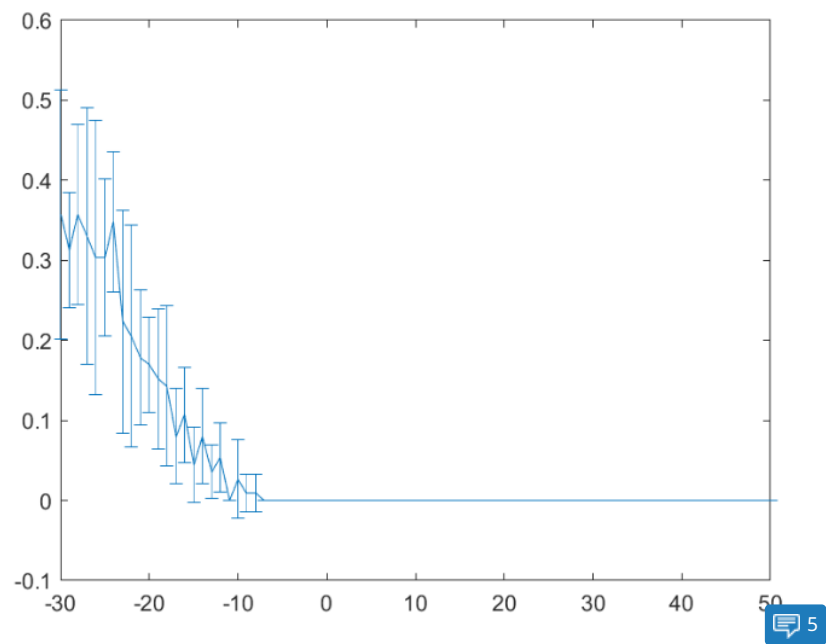


Figure 9: FSK simulation results

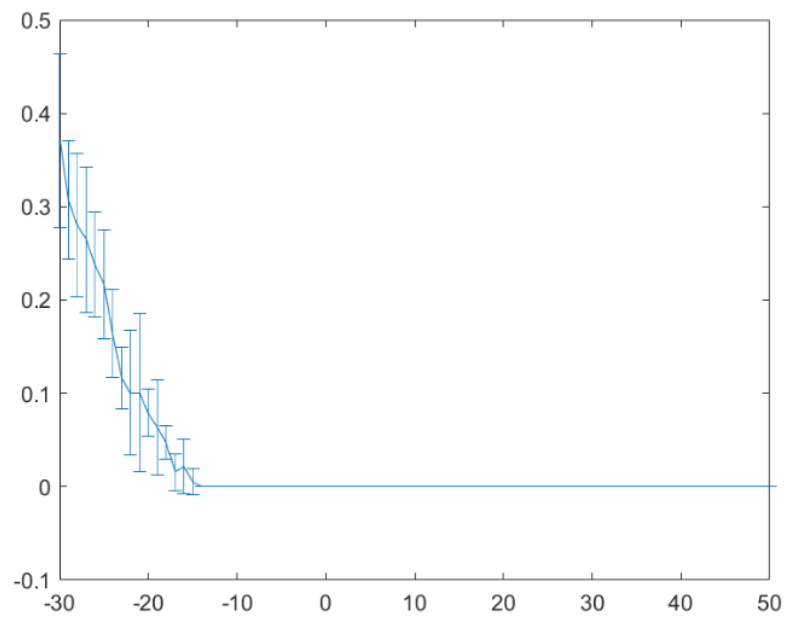


Figure 10: QPSK simulation results

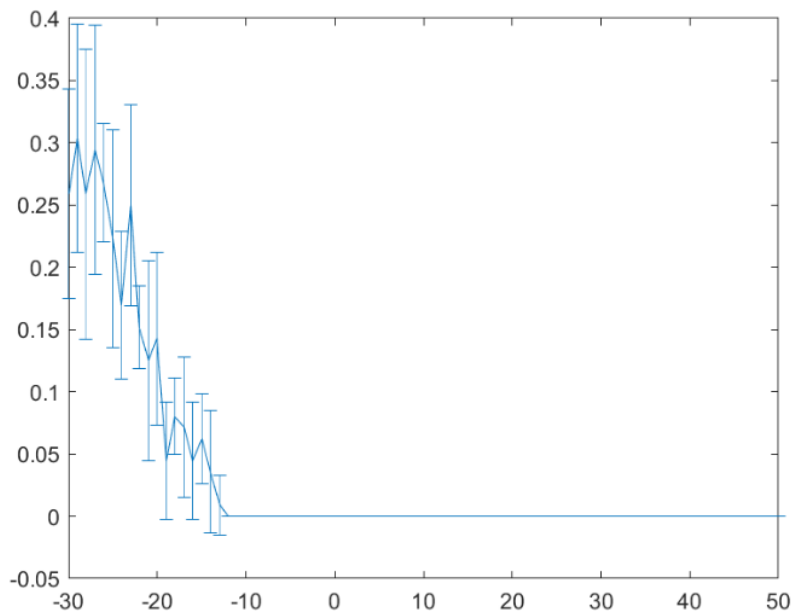


Figure 11: ASK simulation results

Conclusion



QPSK performed the best of the three digital signal modulation techniques explored through simulations using MATLAB Simulink. Further work could investigate the performance of Quadrature Amplitude Modulation (QAM) in the same environments with noisy channels. Different types of noise could be introduced into the system to evaluate the performance of each modulation technique in the presence of different sources of interference.

Bibliography

[1] Texas Instruments, "Teaching DSP through the practical case study of an FSK Modem," Texas Instruments, [Online]. Available: <https://www.ti.com/lit/an/spra347/spra347.pdf>. [Accessed 16 10 2023].



[2] S. S. Haykin, "Digital communications systems," in *Digital communications systems*, Wiley, 2014.

Annex 1 – Signal to noise ratio values used in MATLAB

```
SNR = [50, 20, 10, 5, 2, 1, 0, -1, -2, -5, -6, -7, -8, -9, -10, -11, -12, -13, -14, -15, -16, -17, -18, -19, -20, -21, -22, -23, -24, -25, -26, -27, -28, -29 -30];
```

Annex 2 – MATLAB Script used to repeatedly run simulations and save results – ASK example



File:run_ask.m

```
clear;

% Carrier Frequency
cf = 2*pi*10;
% Message Frequency
mf = 2*pi/10;
% Sample time
sample_t = 1/1000;
% SNR values for each run
SNR = [50, 20, 10, 5, 2, 1, 0, -1, -2, -5, -6, -7, -8, -9, -10, -11, -12, -13, -14, -15, -16, -17, -18, -19, -20, -21, -22, -23, -24, -25, -26, -27, -28, -29 -30];
% Number of total runs
RUNS = numel(SNR);
% Number of time to repeat each run
REPEATS = 7;

% Variables to store run data
results.err_percent = zeros(REPEATS, RUNS);
results.err_total = zeros(REPEATS, RUNS);
results.symbol_total = zeros(REPEATS, RUNS);

for run_no = 1:RUNS
    clc;
    fprintf('ASK Simulation %d of %d\n', run_no, RUNS);
    for repeat_no = 1:REPEATS
        snr = SNR(run_no);
        ask_sim = sim("ASK.slx");
        results.err_percent(repeat_no, run_no) = ask_sim.err.Data(end, 1);
        results.err_total(repeat_no, run_no) = ask_sim.err.Data(end, 2);
        results.symbol_total(repeat_no, run_no) = ask_sim.err.Data(end, 3);
    end
end

save('ask_results', 'results');
fprintf("Saved ASK simulation results to file.\n")
figure;
errorbar(SNR, mean(results.err_percent), std(results.err_percent));
saveas(gcf, 'ASKResults.png')
```

60/100

PAGE 1

PAGE 2

PAGE 3



Comment 1

I didn't ask for FSK. Please read the question.



Comment 2

Good abstract

QM

Misplaced apos.

Misplaced apostrophe:

An apostrophe can function to indicate a possessive when accompanied by an -s ("the book that belongs to Roy" = "Roy's book"). For words that already have an -s at the end, just adding the apostrophe will do ("the team belonging to the boys" = "the boys' team"). Certain exceptions to this rule apply, and possessive personal pronouns ("like ours," "yours," "hers," "his," "its") are possessive already and therefore do not take an apostrophe. It is always wrong to use a possessive apostrophe to simply make a word plural.

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Comment 3

These two carrier frequencies are very far apart



Comment 4

You have stated that your carrier and message frequencies are both 10Hz



Comment 5

I feel as though these graphs could benefit from a more appropriately scaled x axis.

It would also be nice to see all the data on one graph, this would allow a more direct comparison to be made



Comment 6

Where is your discussion section? You should always discuss the results as it allows you to show the reader how you formulated your conclusions.



Ref Qty

I was hoping for more references



Comment 7

Very good use of the available tools

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty

-  Inclusion of a range of research-informed literature, including sources retrieved independently. Referencing conventions mostly consistently applied.

5**KNOWLEDGE & UNDERSTANDING**

Knowledge of the basic underlying concepts and principles of a subject.

-  Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.

12**COGNITIVE & INTELLECTUAL**

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.

-  Evidence of some logical, analytical thinking and some attempts to synthesise, albeit with some weaknesses.
Some evidence to support findings/ views, but evidence not consistently interpreted.

13.5

Some relevant conclusions and recommendations,
where relevant

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



An advanced application of a range of methods, materials, tools and/or techniques.

The context of the application is well considered, with extensive use of relevant examples.

Application and deployment extend beyond established conventions. Innovation and creativity evident throughout.

22.5

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate professionally and, confidently in a suitable format.

Work is coherent, very fluent and is presented professionally.

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