

PSDE5014, Assignment 1

by Joseff Jones

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HND Electrical and Electronic Engineering

PSDE5014 – Signals and Digital
Communications
Assignment 1 – Signals and Modulation

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1. Introduction, Aims and Objectives

This report highlights the efforts made towards investigating wireless technologies – research was carried out into several topics related to wireless technologies, such as the development of radio and the effect it's had on the modern world, the principle of a transmitter/receiver system, various analogue modulation techniques, and an overview of the development of digital radio. A number of signals were analysed and refined mathematically in both time and frequency domains, and a practical investigation involving frequency modulation was also carried out with the hopes of further understanding the behaviour of digital and analogue signals along with their modulation.

2. Research into Radio Systems

Radio is the technology of transmitting and receiving electromagnetic waves of a particular frequency (between 3kHz to 300GHz) in order to communicate information wirelessly over a vast range of distances. The most common use of radio is to transmit sound, which is how radio programmes work; radio can also transmit video/pictures, which is how television programmes are possible.

2.1 – The Development of Radio Since its Invention

The first proof of existence of radio waves was in 1886, when a German physicist named Heinrich Hertz discovered that he could discharge static electricity into one coil to produce a spark in another coil a meter away. In 1895, an Italian inventor named Guglielmo Marconi was able to successfully transmit radio signals for about 1.5 miles “by experimenting with a reproduction of Hertz’s equipment” Einspruch (1998, p. 20), he then went on to patent the first wireless telegraphy system and is often credited as the inventor of radio. In 1915, speech was first transmitted from New York to San Francisco. In 1918 during World War I, Armstrong invented the superheterodyne (superhet) receiver, which is still a vital component used today, it is a receiver that makes use of frequency mixing technology. By 1920, daily radio programmes were being transmitted and by 1922 it was possible to transmit two-way information to ships “stationed 400 miles at sea. However, it was not until 1929 that high seas public radiotelephone service was inaugurated.” (Bellis, 2017). Pulse code modulation is a method of digitally quantizing and representing analogue signals that have been sampled – in 1937, Alec Reeves proposed its use for voice communication via radio signals and later patented the idea, “which laid the foundation for nearly all present-day digital communication systems” (Grant, 2009). 1945 is when geostationary satellite communication was conceived by Arthur C. Clarke, but the first successful instance of this wasn’t until nearly two decades later, when the first satellite of its type was launched in 1963. By the 1970s, the design of satellite had dramatically improved and telecommunication traffic saw a large increase in volume. By the 1980s, personal communications e.g. mobile phones were being developed and means of transferring voice, data and video were becoming much more common.

2.2– The Effect it has had on the Modern World

Radio is ubiquitous in the modern world as it serves as one of the most popular means of communication due to its reliability, cheap cost and efficiency. It is perhaps most commonly used for mobile phones to allow a two-way flow of information between point-to-point, it is also used to allow the broadcast of radio and television in a one-way flow of information. Due to its communication capabilities, radio has become a steadfast tool of communication for pilots, emergency services, ship captains and many more which has resulted in more efficiency and safety for a number of jobs. Radio programmes provide entertainment for a wide audience of people in the form of music and comedy, and also provide invaluable information about the world in the form of news reports.

2.3 – A Transmitter/Receiver System to Block Diagram Level

In order to control radio waves to produce radio communication, two primary components are required – a transmitter and a receiver. A transmitter consists of multiple components which help to generate radio waves which contain data to be transmitted; a receiver complements the transmitter by using an antenna to receive the radio waves produced by the transmitter and extracting the desired data.

Transmitter

Below is a block diagram of a transmitter along with a description of how it works.

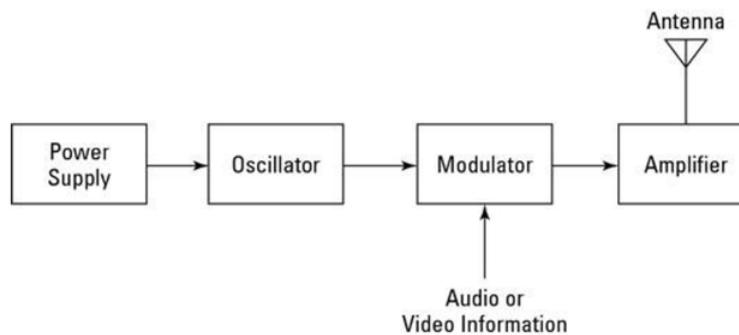


Figure 1 - Transmitter Diagram from dummies.com

The power supply supplies the required power for the transmitter to work correctly and efficiently.

The oscillator generates a sine-wave at a desired frequency, the sine-wave produced will be used to carry the data produced by the modulator and is called a carrier wave.

The modulator, as explained above, adds the data to the carrier wave produced by the oscillator, it achieves this by either increasing or decreasing the frequency of the carrier wave, which produces a modulated FM signal voltage.

The amplifier adds power to the modulated FM to be transmitted, the more power added at this stage the more powerful the broadcast is.

The antenna in this case converts the modulated FM to a radio signal to be transmitted.

Receiver

Below is a diagram of a receiver along with a description of how it works.

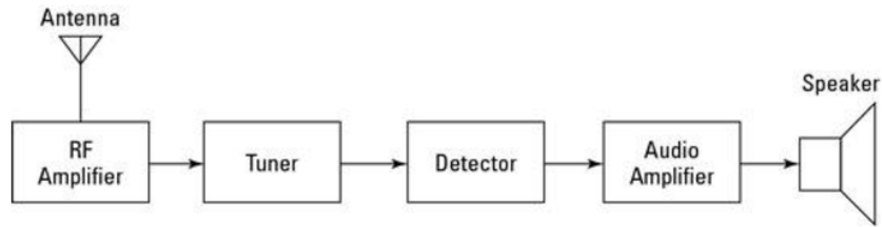


Figure 2 - Receiver Diagram from dummies.com

The antenna in this case is used to collect the radio signals produced by the transmitter's antenna, but it also picks up radio signals from other sources which needs to be rectified later.

The RF amplifier *amplifies* the signal collected by the antenna, as the radio signal loses power as it is transmitted from the transmitter.

The tuner extracts signals of a desired frequency from the radio signals picked up from the antenna, removing the unwanted signals.

The detector (or demodulator) essentially unpacks the carrier wave to separate the wanted information from the rest of the signal.

The signal produced by the detector is very small and so another amplifier (in this case an audio amplifier) is used to amplify the signal so that it can be used by a speaker.

It's worth noting that the above diagrams are very basic, and that a typical modern receiver would most likely incorporate superheterodyning before demodulating, this means a local oscillator is included which, according to Grant (2009, p. 9), "enables higher gain and greater selectivity to be achieved in order to increase rejection of unwanted interfering signals".

2.4 – Various Analogue Modulation Techniques

Analogue modulation is a way of transferring an analogue signal over another analogue signal at a different frequency, thus creating a sort of “packet” of data. The two most common types of modulation are continuous-wave modulation and pulse modulation, but each of those types of modulation can be broken down further.

Continuous-wave Modulation

Continuous-wave modulation is when a sine-wave is used as a carrier-wave. This is then broken down further down to amplitude or angle modulation; amplitude modulation is when the amplitude of the carrier-wave is varied to work with the modulating signal and angle modulation is when the angle of the carrier wave is varied to work with the angle of the modulating signal.

Pulse Modulation

Pulse modulation is when a square-wave is used as a carrier wave. For analogue modulation, the duration, pulse width or location of the carrier-wave is varied to work with the modulating signal.

2.5 – An Overview of the Development of Digital Radio

Digital radio comes in a number of forms and is used extensively in modern society – digital TV is perhaps the most common use of digital radio, there are also digital radio stations which can also be streamed via intranet. Digital devices tend to be much more portable than analogue devices, and so digital radio has caught on for several devices such as mobile phones.

Digital radio began its development in Europe in 1981 at the “Institut für Rundfunktechnik” (The long, slow birth of DAB radio, 2010) and was further developed with the development of the DAB (Digital Audio Broadcasting) standard. It was first transmitted domestically in 1995 via the BBC, with commercial DAB receivers being widespread in 1999. DAB was considered a potential replacement for FM radio, offering a lot of the qualities of FM such as high-quality data transfer but with the advantages of digital standards such as easier tuning of radio receivers, a larger (global) reach, a more efficient display of other formats such as text along with audio, and an increased capacity of transmission. Many predicted in the late 90s that digital radio would render analogue radio obsolete, but it is clear now, nearly two decades later, that analogue radio still has a purpose.

3. Experimental Methods

Part of the assignment was to carry out a practical activity on frequency modulation in which a signal source module has its frequency modulated by a sinewave generator; the results of the frequency components are then displayed by sweeping it with a function generator beyond the fixed pass frequency of a crystal filter. The apparatus was connected to a picoscope which was then connected to a PC via USB, the picoscope was able to provide oscilloscope and frequency meter functions and graphs were produced based on the apparatus' outputs - channel A of the picoscope was the message signal, and channel B was the carrier signal. The objectives of the experiment are to: verify the Bessel coefficients for side-frequency amplitudes, understand that a carrier can be modulated by altering its frequency with regards to the signal, understand that an FM signal has many sidebands, and that those sidebands are dependent on the frequency and amplitude of the signal, and to understand that FM is more stable than AM with regards to interfering signals, but has an increased bandwidth.

4. Testing and Result

Testing for the practical involved altering a number of attributes of the system in order to measure the response and observe the system's behaviours; some of these measurements could be compared to values calculated using mathematical theory.

The first test of the practical was to find out what was happening to the frequency when there was no attenuation, max sensitivity, the frequency was set to 455kHz and the modulation generator was set to 1Hz at 6Vp-p – the result being a 455kHz average with a 102kHz deviation each side, with 350kHz minimum and 550kHz maximum, with a voltage of 760mV. The figure below shows that.

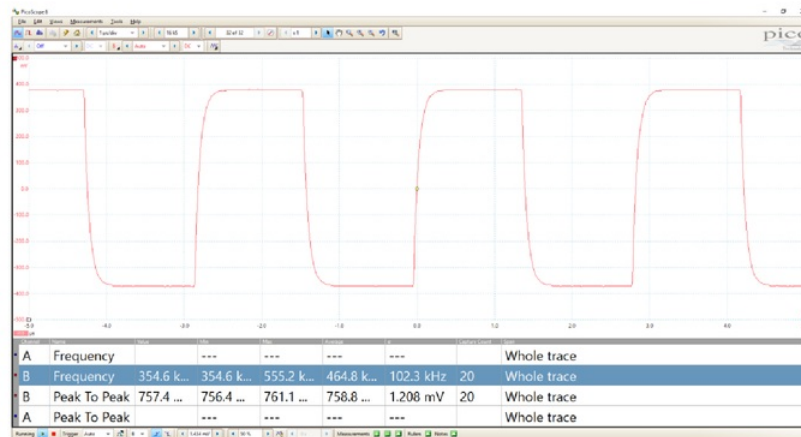


Figure 3 - Setting Oscilloscope to 455kHz

The next test to carry out was to reduce the amplitude of the modulation generator in 1V steps and to record what happens to the carrier frequency deviation. The figure below shows the voltage at 5V.

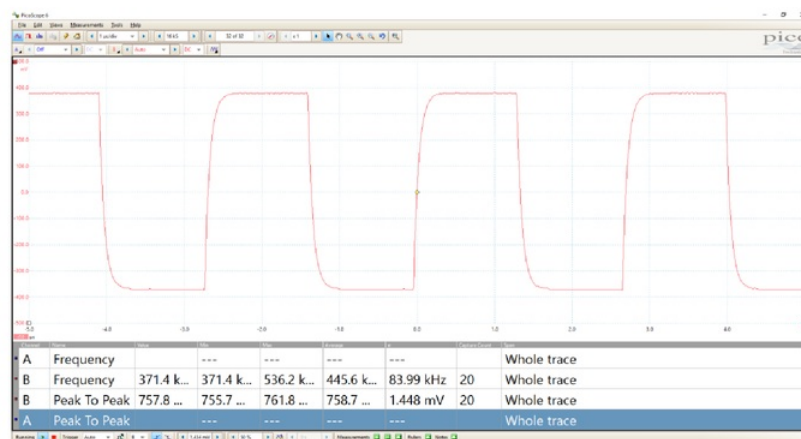


Figure 4 - Reducing the Amplitude in 1V Steps, 5V

The only thing that noticeably changed was the frequency deviation, stepping the voltage down further proved that was what was happening, shown in the figure below.

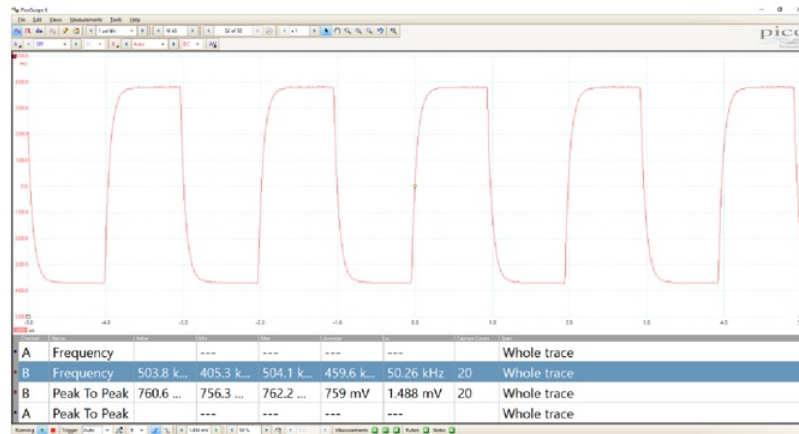


Figure 5 - Reducing the Amplitude in 1V Steps, 3V

The frequency deviation at 3V is 50kHz, which is half the frequency deviation of the 6V - frequency deviation is proportional to amplitude.

The next part of the test involved adjusting the modulation generator's output to 6v and then adjusting the B control on the signal source module until the deviation becomes 60kHz; the frequency of the modulation generator is then raised to 10Hz, then to 100Hz to observe the response of the oscilloscope. The response of the oscilloscope wasn't measurable, but it was obvious that the response was easier to read when the frequency was lower and so when the frequency is higher, the change is harder to see due to the wave flickering on and off the screen.

The final test involved setting the modulation generator to produce an amplitude of 2V at 20kHz and the picoscope to spectrum analyser mode – this produced a range of side-frequencies, the software was set up to focus on 455kHz as that is what the manual frequency control was producing. Below is a figure showing what the spectrum analyser was showing initially.

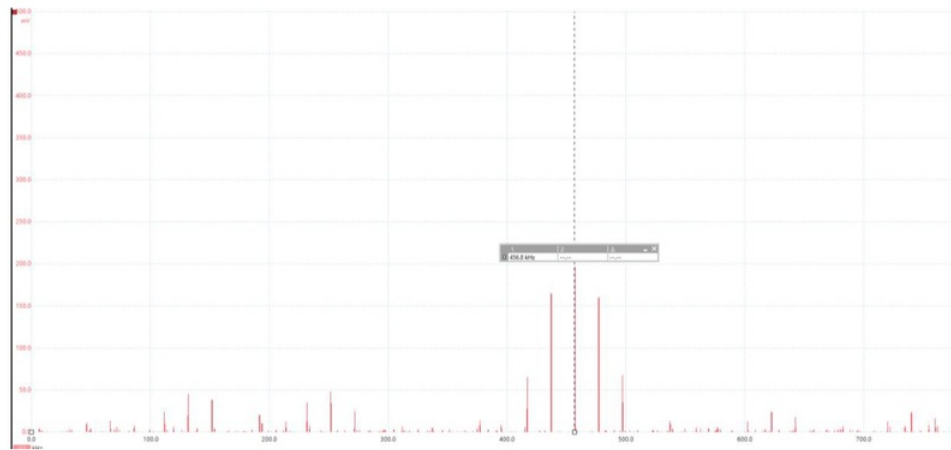


Figure 6 - Spectrum Analyzer @2Vp-p

Zooming into the spectrum analysis of the 2V 20kHz signal showed that there were two significant pairs of sideband frequencies, with a frequency deviation of approximately 20kHz (calculated using $f_{max}-f_c$). According to calculations, there is a deviation ratio of 1 as the frequency deviation of 20kHz divided by the signal frequency of 20kHz is 1; according to the Bessel table, a deviation ratio of 1 should produce four sidebands, which is what is observed, shown clearly in the figure below.

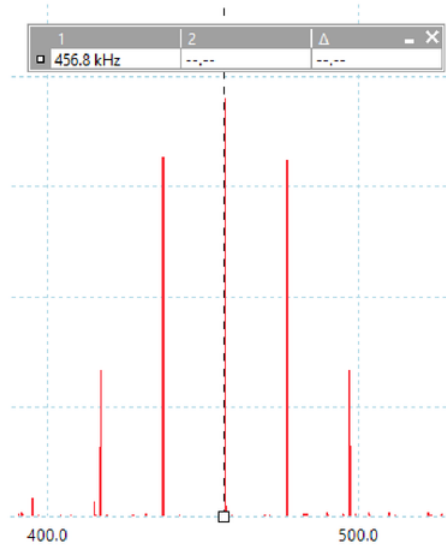


Figure 7 - Spectrum Analyzer @2Vp-p Zoomed

Increasing the voltage of the modulation generator from 2V to 4V had the effect of doubling the frequency deviation, indicating that the frequency deviation is proportional to amplitude, as was proven earlier. Calculating the deviation ratio for the 4Vp-p signal produced a deviation ratio of 2; according to the Bessel table, this should produce six significant sidebands, or three pairs of significant sidebands – this is shown to be true in the figure below.

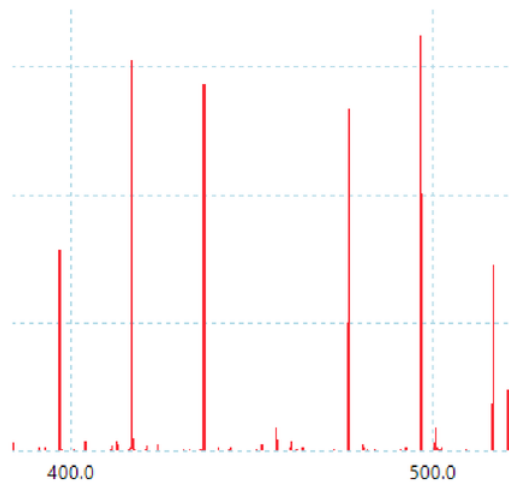


Figure 8 - Spectrum Analyzer @4Vp-p Zoomed

Increasing the voltage of the modulation generator further up to 6V increased the frequency deviation to 60kHz. Calculating the deviation ratio for the 6Vp-p signal produced a deviation ratio of 3; according to the Bessel table, this should produce seven significant sidebands – this was a little harder to see from the spectrum analysis, but it can be seen that there are four significant sidebands on the left and three on the right.

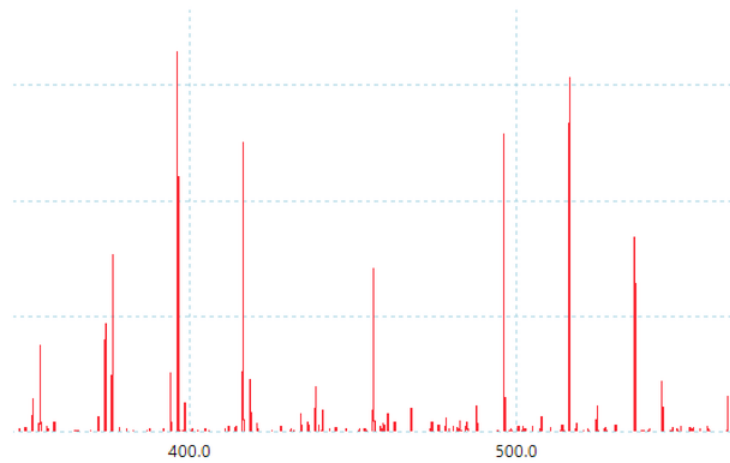


Figure 9 - Spectrum Analyzer @6Vp-p Zoomed

5. Conclusions

With regards to the research – over the year, radio technologies have proven to be of utmost importance for the safety of everyday people, the efficiency of workers, and the communication of important information. The development of radio has been going on for over a century, but it has spawned numerous technologies along the way and has shaped the modern world, the research indicated that it has been perhaps the most important technology for advancing civilisation in modern times. The design of radio has remained similar to its design at its inception but has refined with new components and developed theories to work with, such as types of modulation.

With regards to the practical – a number of things were learnt from the practical investigation, namely that frequency deviation is proportional to amplitude and that the number of sidebands for a signal can be determined using the signal frequency and frequency deviation to determine the deviation ratio and then using a Bessel table. The practical results that were measured corroborated with the results of the calculations (found in the appendix), but if the test were to be taken again, more results would be measured (such as the J0, J1, J2 etc. values) in order to compare with the Bessel table further.

6. Reference List and Bibliography

- Bellis, M. (2017). *The Invention of Radio*. Retrieved from thoughtco.com:
<https://www.thoughtco.com/invention-of-radio-1992382>
- Bodanis, D. (2006). *Electric Universe: How Electricity Switched on the Modern World*. Broadway Books.
- Einspruch, F. S. (1998). *Electronic Genie: The Tangled History of Silicon*. Illinois: Alfred P. Sloan Foundation.
- Grant, I. G. (2009). *Digital Communications*. Pearson Education M.U.A.
- The long, slow birth of DAB radio*. (2010). Retrieved from BBC.co.uk:
<http://www.bbc.co.uk/news/10569231>

7. Appendix

The next page includes the calculations made towards the assignment.

Assignment 1 -

1) A 455 KHz carrier has an amplitude of 375 mV and is frequency modulated by a 10 KHz square-wave signal of amplitude 1.5 V. The resulting carrier wave varies between 425 KHz and 485 KHz.

2) Determine the maximum frequency deviation for this FM wave and calculate the modulation index.

Carrier amplitude, $E_c = 375 \text{ mV}$

Signal amplitude, $E_s = 1.5 \text{ V}$

Carrier frequency, $f_c = 455 \text{ KHz}$

Signal frequency, $f_s = 10 \text{ KHz}$

$$\begin{aligned}\text{Frequency Deviation } \Delta f_c &= f_{\max} - f_c \\ &= 485 \text{ KHz} - 455 \text{ KHz} \\ &= \underline{30 \text{ KHz}}\end{aligned}$$

$$\text{Modulation index } B = \frac{\Delta f_c}{f_s} = \frac{30 \text{ KHz}}{10 \text{ KHz}} = 3$$

$$2) J_0 = -0.26 \times 375 \text{ mV} = 0.10125 \text{ V}$$

$$J_1 = 0.34 \times 375 \text{ mV} = 0.1275 \text{ V}$$

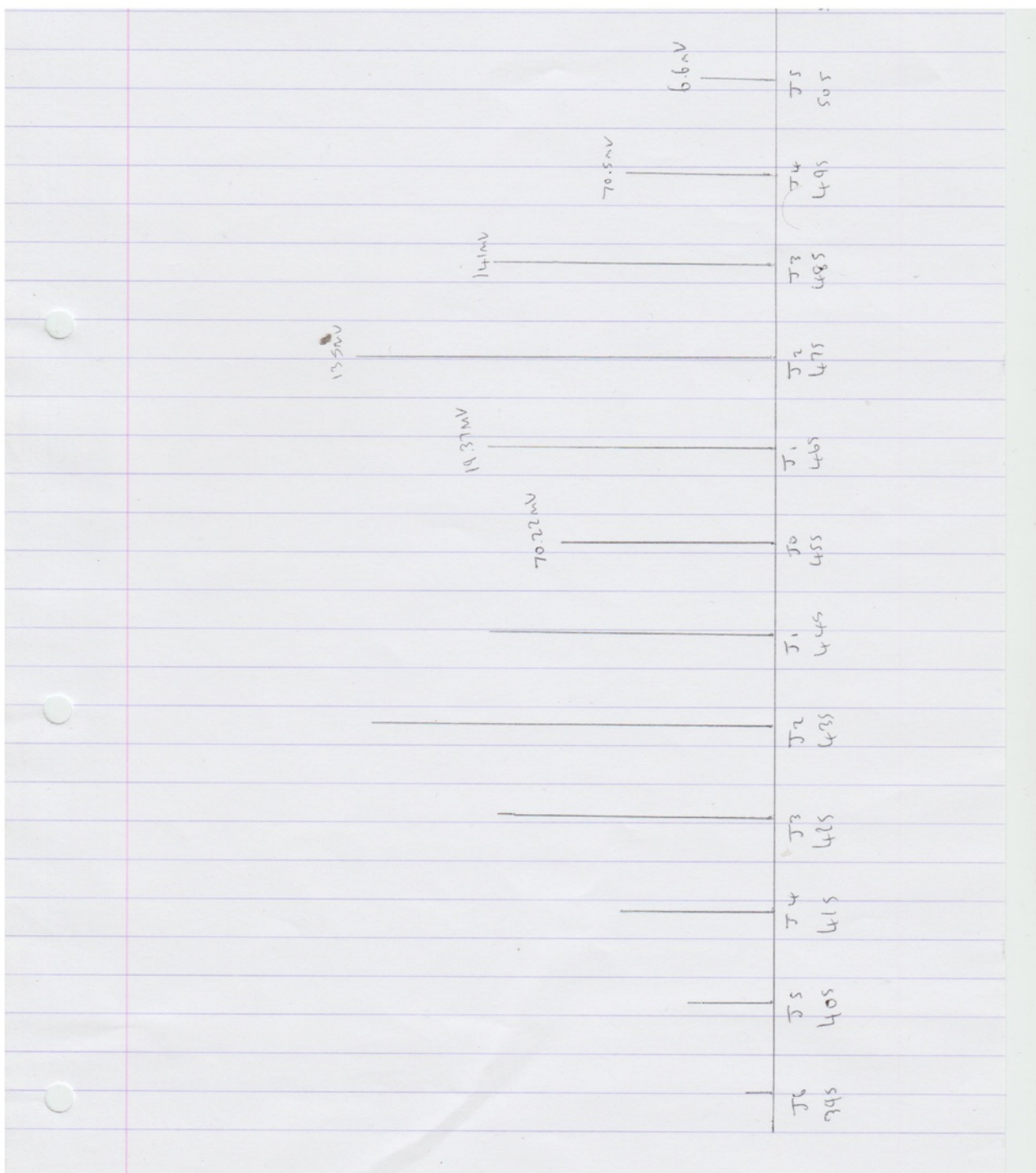
$$J_2 = 0.49 \times 375 \text{ mV} = 0.18375 \text{ V}$$

$$J_3 = 0.31 \times 375 \text{ mV} = 0.11625 \text{ V}$$

$$J_4 = 0.13 \times 375 \text{ mV} = 0.04875 \text{ V}$$

$$J_5 = 0.04 \times 375 \text{ mV} = 0.015 \text{ V}$$

$$J_6 = 0.01 \times 375 \text{ mV} = 0.00375 \text{ V}$$



PSDE5014, Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

62/100

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GRADING FORM: CSG-RUBIC

RESEARCH-INFORMED LITERATURE



There was good evidence of further reading and research from credible and reliable sources. Your interpretation and understanding of the additional research was good and demonstrated a very good underlying appreciation of the subject. Your references were appropriate to the task. Your reference list was of a but short for this assignment, since it contained a high research value.

7

KNOWLEDGE AND UNDERSTANDING



The knowledge and understanding of the subject demonstrated by this assignment was generally good. There were very few gaps in your knowledge of the basic principles and your understanding of the higher level concepts was demonstrated to a limited degree - you could have explained in more detail how FM worked. The calculations were mainly included in the annex, but they were not referenced by the main report. Further work – Your explanations need to be more detailed and written in a clear manner within the report, do not rely on annexes in isolation.

20

ANALYSIS



Your analysis of the task was generally satisfactory, both in class and as shown in this assignment. You have demonstrated some analytical skills and your

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approach to the task was logical. You carried out a short analysis and a short conclusion. Further work – in your conclusion, you should relate the results to the original specification and to accepted theory.

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task were generally OK, you used the resources appropriately when carrying out the experiment and you used appropriate options for testing and evaluating the circuit performance - albeit to a limited fashion. Testing generally lacked a lot of the required detail however and you should have included a comprehensive set of results for each stage.

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SKILLS FOR PROFESSIONAL PRAC.



In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was generally good and contained most of the required detail, it was also written in a coherent and logical way. Try not to get too reliant on handwritten annexes though unless they are properly referred to.

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