

PSDE 5015 Ass 1 S Dedoncker FINAL SUBMISSION

by Scott Dedoncker

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HND Electrical & Electronic Engineering

PSDE 5014: Signals & Digital Comms



Assignment 1

Signals & Modulation

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1. Research into Radio Systems

1.1 The Invention, Development and Effects of the Radio and Digital Radio on the Modern World

Radio signals/waves and the manipulation of them over the last two centuries have influenced some of the biggest events and progressions in economic, engineering and political development spanning all four corners of the globe. The development of the radio as we know it today, cannot be accredited to any one individual, but a collective of people spanning from the beginning of the 19th, and into the turn of the 20th century, all developed techniques in radio wave manipulation and communication that lead to the ease of long distance radio communication today.

The development of the theory of electromagnetism by James Clerk Maxwell and his publishing of "A Treatise on Electricity and Magnetism" is what initially kick started serious interest in possible wireless communication using radio waves. Maxwell used investigative work by other pioneers of the era such as Michael Faraday and Heinrich Rudolph Hertz, and their works on the relationships between that of electricity and magnetism to derive his theory.

(Harman, 2001)

Hertz actually went on to, and is credited as being one of, if not the first, person to transmit a controlled radio frequency and receive it. His experiments were carried out in order to confirm Maxwell's earlier theory of electromagnetism based off of Hertz' previous work. Hertz' research culminated in the experimentation of transmitting electro magnetic waves using what was known as the Hertz spark-gap transmitter. In modern day technology this would be known as a half wave dipole oscillator. The oscillator involved two capacitors of a 30cm diameter, and a 3 metre distance with two copper wires running from either end with a minute gap where they would meet to allow sparks to arc across. When a voltage was applied across this gap. This allowed radio waves (electromagnetic waves at the time) to emit from the transmitter. Even though this was a ground breaking discovery, Buchwald (Buchwald, 1994) states that Hertz did not believe these waves were practical or a significant discovery.

(Buchwald, 1994) (Harman, 2001)

Hertz' discovery would change the word of communication as we knew it however. Guglielmo Marconi used Hertz techniques to transmit the first long distance radio wave across the English Channel in 1899. In December 1901 he sent the first transatlantic radiotelegraph message of the letter "S" from Cornwall, England to Newfoundland, Canada by methods of Morse code. This is widely regarded as the ground breaking and historical event that paved the way for wireless communication throughout the 20th century and what would be known as the common Radio.

(Regal, 2005)

By 1906 Reginald Fessenden had paved the way for the possibility of transmitting human voice using amplitude modulated radio waves, now known as AM radio. Using theory from a previous experiment of his in 1900, on Christmas eve of 1906 he sent the first radio broadcast using an altered version of Hertz' spark-gap transmitter. This broadcast played the song "O Holy Night" and a passage from the bible. This along with World War 1 about to break on the horizon, would increase the speed of development of the Radio.

(Belrose, 2002)

World War 1 and 2 can be indirectly accredited for the acceleration of the development of the radio, due to communication being vital in times of conflict. After the First World War, and the development of vacuum tubes thanks to John Ambrose Fleming, the first commercial broadcast of radio began to pop up across Western Europe and the Americas. This was due to the increased efficiency of transmitters and receivers. These continued to grow in size and popularity until the 1930's when American inventor Edwin Howard Armstrong patented FM radio. FM (frequency modulation) was revolutionary due to its methods of using carrier waves for information transmission and varying instantaneous frequencies, as opposed to AM transmission where the opposite is done. This method of radio transmission reduced the amount of electrical interference (static) carried over the transmission. This also kick-started the production of television broadcasts in the UK and United States. By the start of the Second World War in 1939 FM television sets were commonplace, and the first FM radio station has been constructed in the U.S. by the second half of the century the technology had advanced to the point where FM radio stations broadcasting for entertainment was a daily occurrence. Television sets had also advance to the point where they were found in most households. The technology continued to improve leading colour television becoming the norm.

(Regal, 2005)

The next step in development for the radio would turn out to be digital audio broadcasting, or DAB for short. Digital radio began its development late into the 20th century being pioneered by small research groups in the UK, Norway and Sweden. It lead to the first digital radio broadcasts in 1995 by said countries. The main pro for a digital signal is that it is so much clearer and carries very little interference compared to FM waves. This is done by methods of compression. There are also no methods of retuning at the receiver due to the technologies ability to mask any and all interference. The digital signal is produced at the transmitter and sent via various carrier waves, about 1500 times more than a regular analogue wave, and is immediately compressed by reducing its data rate before sending. Once received by the various receives, the signal is stripped of all unnecessary interference caused by building, environments and other electrical interference. This is done in means of removing sounds or frequencies that are smaller, or less relevant to the receiving end. The result is a very clear, almost CD like quality sound from the received signal. Another added benefit to digital transmissions is that they can carry other data from along with the audio. For example when using a digital radio and listening to a song broadcast by a station, more often than not the screen on the radio will display what radio station is being broadcast, the song name, and possibly presenters of the broadcast.

(Wolfgang Hoeg, 2009) (Woodford, 2017)

1.2 A Transmitter/Receiver System Block Diagram

Shown in figure 1 is a basic build of how a radio system works. It shows all its key parts from how a frequency is created, transmitted and received.

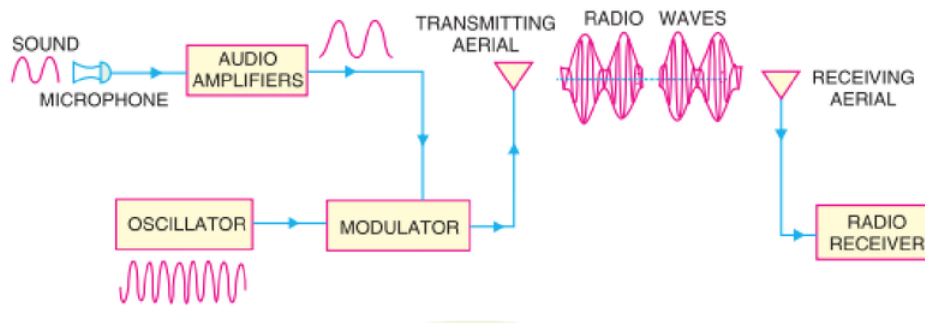


Figure 1 - Transmitter/Receiver System Block Diagram (Talking Electronics, 2016)

The diagram begins with the transmission stage. This is found in the broadcasting location and is the source of the radio signal. Components for this stage include:

- Microphone – This device is used to take real world sound and convert their waves into radio signals. This is done by using varying air pressure on the surface of the microphone to create a frequency relationship between the original signal, and a new electrical signal. This then feeds the audio amplifier.
- Audio Amplifier - This device's primary purpose is to raise/strengthen weak signals ready for transmission. This is done by a process of multistage cascading and the product is then supplied to the Modulator.
- Oscillator – The oscillator is there to provide the carrier waves used to transmit the frequency. This wave needs to be of a significant enough level so that it can carry the amplified audio wave. It also needs to be powerful enough to carry over large distances. Without this device the signal would not transmit anywhere. This carrier wave is then fed and meets the amplified audio signal at the Modulator.
- Modulator – With both wave and signal meeting here, they are merged onto one another. This gives the product of a modulated wave.

The second stage to this diagram is the transmission stage. This is done using an aerial or antenna and emits the modulated waves into the atmosphere at the speed of light by methods of electromagnetic waves/radiation, but with much longer wave lengths due to oscillation. These radio waves can travel for vast distances depending on the oscillator power at the source, even as far as into space.

The third and final stage of the system is the radio receiver stage. Once a receiving antenna picks up the desired signal, based on what frequency it is tuned too, a ting e.m.f is induced into the antenna from the radio waves. Once this low voltage reaches the receiver from the antenna, it is amplified and demodulation begins in order to dissect and extract the original audio picked up by the microphone. Once this has been done and the original signal reconstructed, it is fed to desired speakers and emits similar sound waves to the ones captured at the beginning. All of this is done at incredible speeds.

(Talking Electronics, 2016)

1.3 Various Analogue Modulation Techniques

In order to understand different methods of analogue modulation, modulation needs to be explained. Modulation is a necessity in transmitting radio signals, as it combines the audio signal with an oscillated carrier wave. The modulation process alters some parts of the carrier wave in order to allow the audio signal to slot into it. There is also the process of demodulation at the receiving end of the spectrum, where the carrier frequency is deconstructed and the audio signal extracted to be amplified and produced through a speaker at the other end.

There is no one set in stone way for these two processes to be carried out. There are various methods of modulation that can be looked at including the following three basic methods.

Amplitude modulation is a commonly used method of modulation that varies the instantaneous amplitude of the oscillated carrier waves in line with the audio signal. This is known as one of the easiest and simplest forms of modulation and also one of the cheapest. The downside to this system is that it garners a lot of interference when transmitting.

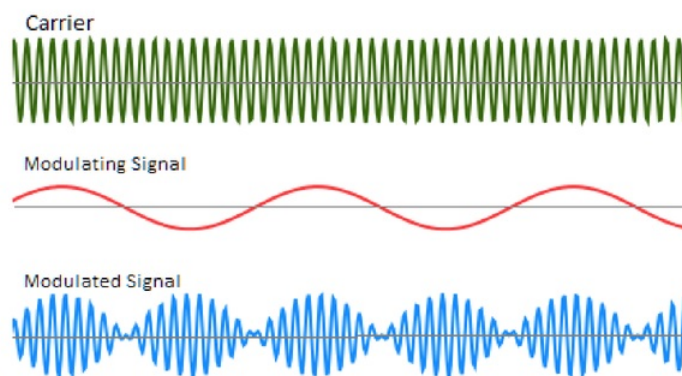


Figure 2 - Am Modulation (Equestion Answers, 2017)

Frequency modulation is another modulation method commonly used. This works in the same way as AM however instead of varying the amplitude, the instantaneous frequency is modulated instead. This improves on AM as the modulation and demodulation process does not pick up as much interference, however the system is slightly more complex than the AM system design.

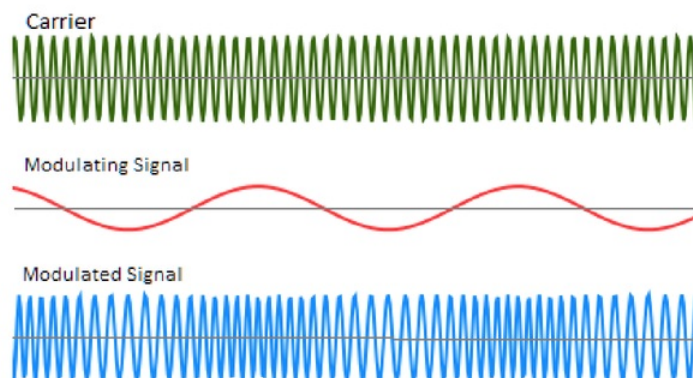


Figure 3 - FM Modulation (Equestion Answers, 2017)

A third method of Modulation involves Phase modulation. This method differs from the previous two as it varies the instantaneous phase in accordance with instantaneous amplitude of the audio signal. This also benefits from not picking up much interference, however this is once again more expensive and complicated than AM or FM.

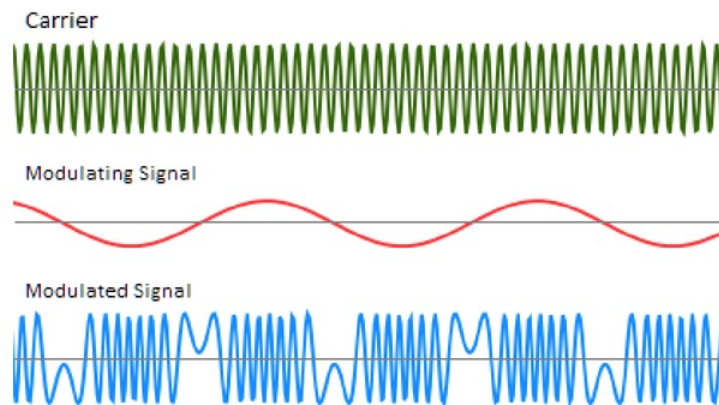


Figure 4 - Phase Modulation (Equestion Answers, 2017)

Along with the three basic types of modulation, there are also three types of digital modulation that can be used to transmit a signal. Digital modulation uses a much more discrete level when amplifying a signal for transmission.

One method of digital modulation is ASK or amplitude shift key. The information transmitted here is in an on/off signal, so the modulated signal is on/off also with information being present when the signal is 1, and information not being present when the signal is 0. This is also known as using a digital high and low to transmit data and can be seen clearly in the modulated signal in figure 5. This type of modulation is used mainly in infrared and fibre optic applications.

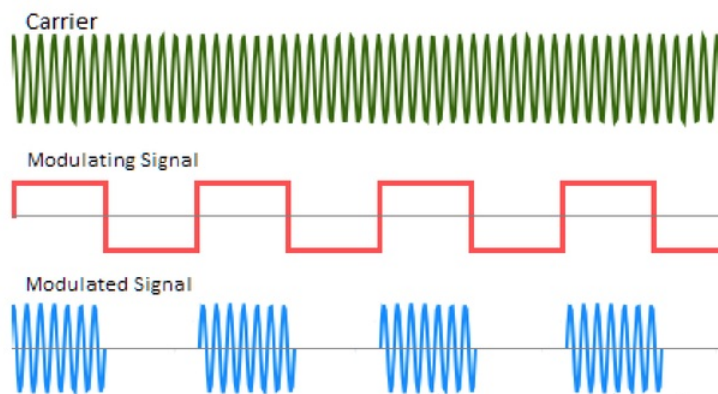


Figure 5 - ASK Modulation (Equestion Answers, 2017)

A second method of digital modulation is FSK or frequency shift key. This is used when varying frequencies of 2 or more are transmitting a signal. This once again uses the process of digital high and digital low to transmit data. This can be seen in figure 6 with the frequency being wider at digital high 1 and tighter at digital low 0. This process of modulation is found mainly inside modems when transmitting and receiving.

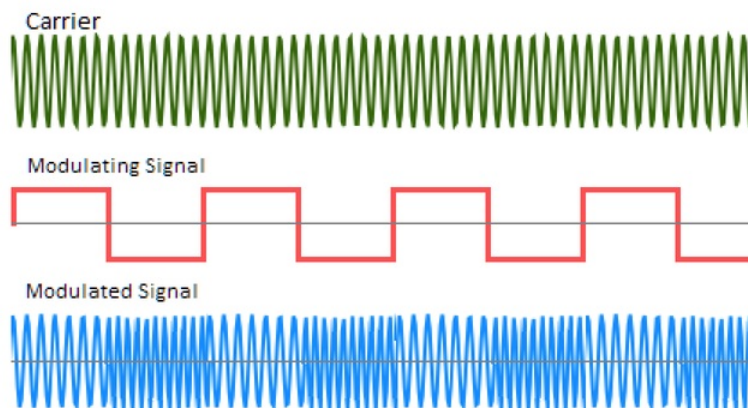


Figure 6 - FSK Modulation (Equestion Answers, 2017)

The third method of digital modulation is PSK or phase shift key. This like phase modulation is uses digital highs and lows when the phase is being modulated for transmission. This is done to send 2bit information. This method is utilised is applications such as mobile communication and satellites.

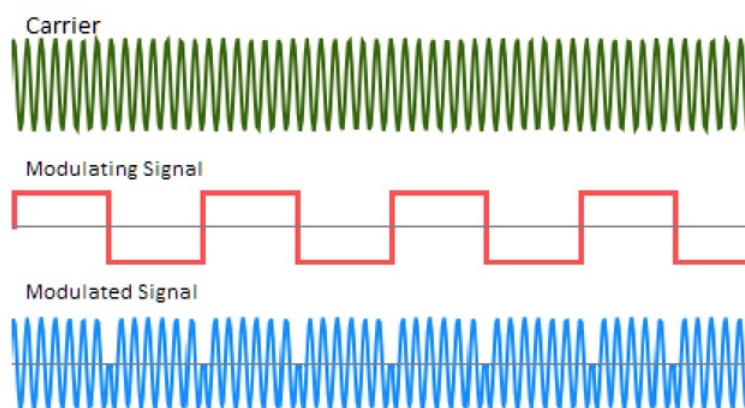


Figure 7 - PSK Modulation (Equestion Answers, 2017)

2. Experimental Method

For the frequency modulation practical of this assignment 3 tasks needed to be completed. This included two calculations that would then produce information used for the third task, that being a practical. The values calculated in task 2 will display a spectrum bandwidth waveform that should show a similar shape to the practical investigation in task 3.

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

$$\Delta f_c = f_{max} - f_c$$

$$\Delta f_c = 485\text{kHz} - 425\text{kHz}$$

$$\text{Max Frequency deviation} = 30\text{kHz}$$

- 2) Calculate the required values and sketch the amplitude spectrum of this wave, clearly indicating the amplitude and frequency of each component and give an explanation of how these values were obtained. Indicate on this spectrum the bandwidth of the waveform.

$$\beta = \frac{\Delta f_c}{f_s} = \frac{30k}{10k} = 3$$

This defines that we use the third row on the Bessel function order table for the following calculations.

m_f	J_0	J_1	J_2	J_3	J_4	J_5	J_6
3.0	-0.26	0.34	0.49	0.31	0.13	0.04	0.01

$$J_0 = 0.26 \times 375\text{mV} = 97.5\text{mV}$$

$$J_1 = 0.35 \times 375\text{mV} = 127.5\text{mV}$$

$$J_2 = 0.49 \times 375\text{mV} = 183.75\text{mV}$$

$$J_3 = 0.31 \times 375\text{mV} = 116.25\text{mV}$$

$$J_4 = 0.13 \times 375\text{mV} = 48.75\text{mV}$$

$$J_5 = 0.04 \times 375\text{mV} = 15\text{mV}$$

$$J_6 = 0.01 \times 375\text{mV} = 3.75\text{mV}$$

The bandwidth spectrum can be seen in figure 8. This details the shape that the modulated frequency should take in the practical experiment. There will be minor, maybe somewhat greater difference in values from the calculated ones, however the shape should remain the same.

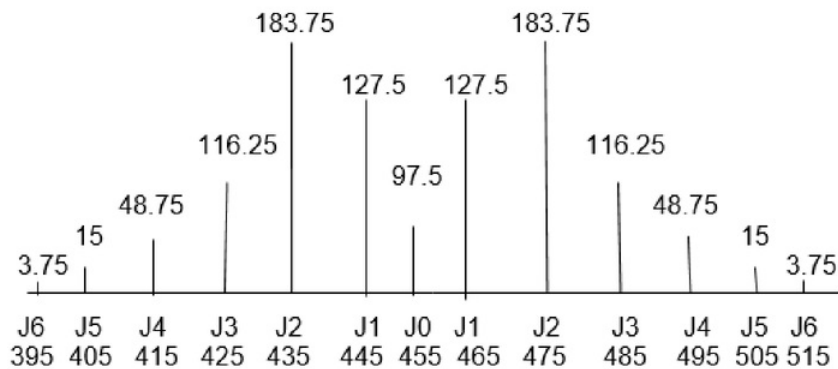


Figure 8 - Frequency modulation spectrum simulation

3. Testing & Results

For the third task a practical was carried out involving 6 of the feedback instruments pack “analogue communications system” in order to confirm the wavelength and values calculated in task 1 and 2. The first stages were to set up the system to produce a frequency modulated signal.

Once this part of the system had been setup, channel A displayed a frequency peak to peak varying from 5v to 0v in 1v steps:

- 5v p-p = +85Khz
- 4v p-p = +70Khz
- 3v p-p = +50Khz
- 2v p-p = +33Khz
- 1v p-p = +16Khz
- 0v p-p = +130hz

This shows the carrier frequency decreases in size as the amplitude of the modulation generator is reduced. This shows that the amplitude of the carrier linearly affects the carrier frequency. Examples of the frequency can be seen below:

3V p-p = +-50 Khz

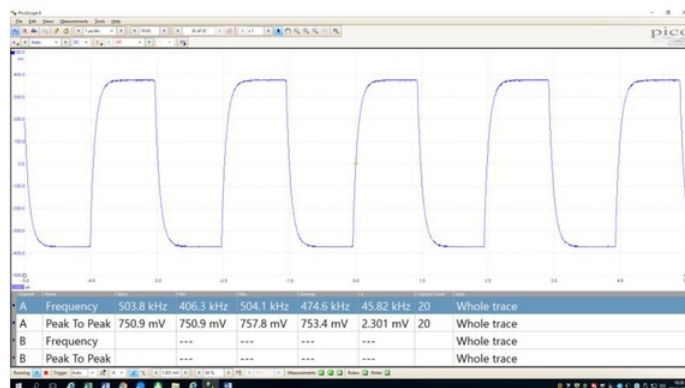


Figure 9 - 3v Peak to Peak Display

1V p-p = +-16 KHz

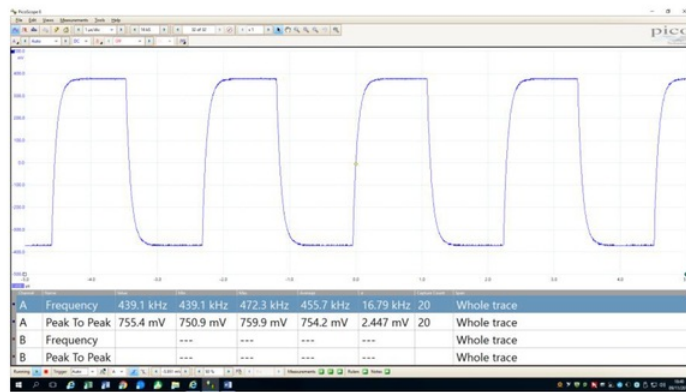


Figure 10 - 1v Peak to Peak Display

The next step was to display the side frequencies and determine the bandwidth for the system. The system was altered in order to accommodate a 20KHz deviation. This determined that gaps between the modulation frequencies. The deviation ratio was also worked out as:

$$\frac{20}{20} = 1 \quad \therefore \quad \frac{\text{Frequency Div}}{\text{Modulated Frequency}} = \frac{20}{20} = 1\beta$$

The system displayed the following frequency modulation spectrum.

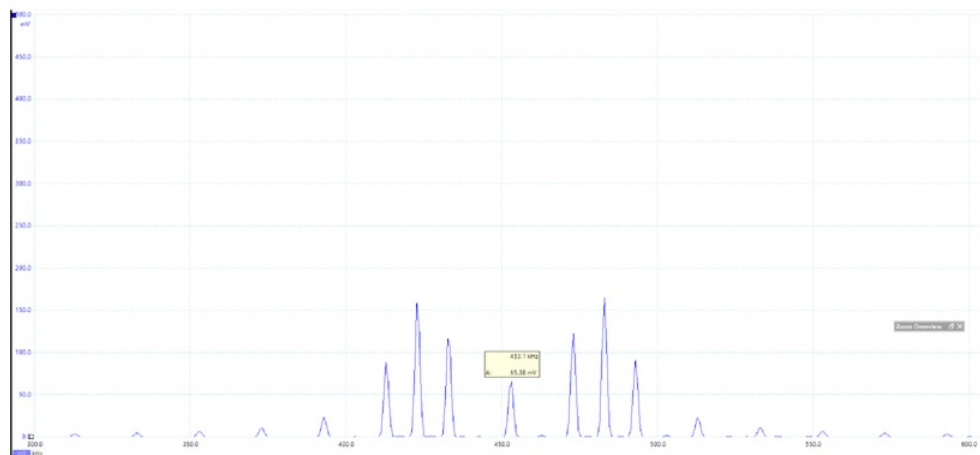


Figure 11 - Simulated Freq Mod Spectrum

The system gave modulation values of:

- J0 = 65mV
- J1 = 115mV
- J2 = 158mV
- J3 = 89mV
- J4 = 23mV
- J5 = 12mV
- J6 = 6mV

These values do stray drastically from the original calculated values, however this can be put down simply to the inaccuracy of the equipment used. When comparing the shape of the spectrum with the calculated one we can see that they look very similar showing that the calculations were accurate in reality to the practical.

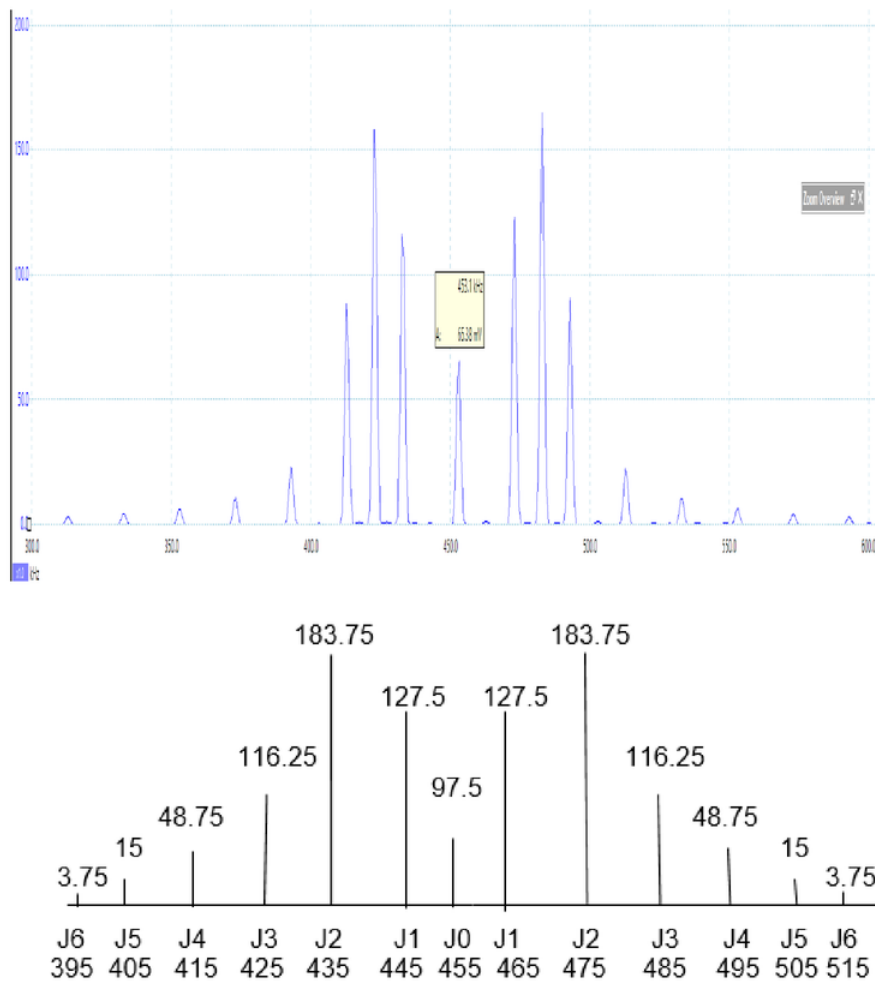


Figure 12 - Spectrum Comparison

4. Conclusions

This assignment was written up to cover the invention, development and practical uses of signals and modulation, specifically in radio. It was divided into two sections, one being research and the other being a frequency practical modulation.

For the research the main areas that needed to be covered were:

- the development of radio since its invention
- the effect it has had on the modern world
- a transmitter/receiver system to block diagram level
- various analogue modulation techniques
- an overview of the development of digital radio

I feel that all of these areas were covered in section 1 of this report thoroughly, showing a clear timeline of the invention and development of radio, how it affected culture in the modern world, the development of digital radios, a detailed analysis of a system block diagram involving radio transmissions, and a good explanation of various methods of modulation including AM, FM, PM, and their digital counterparts.

For the experimental method Task I feel that the calculations were completed clearly and efficiently giving me clear guidance going into the practical. I also believe the relationship between the practical and calculations were shown clearly and the practical was a success.

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6. Appendices

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: CSG-RUBIC

RESEARCH-INFORMED LITERATURE



There was evidence of extensive further reading and research from credible and reliable sources. Your interpretation and understanding of the additional research was very good and demonstrated a deep underlying appreciation of the subject. Your references were appropriate to the task and your reference list was of an appropriate length for this assignment.

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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 design process was well explained for the basic circuits, but not for the overall system.

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ANALYSIS



Your explanation of the experiment was good, however the conclusions lacked some detail. You could have evaluated the results in more detail and specified whether they concurred with theory suggesting reasons for any discrepancies. You have

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however demonstrated good analytical skills and your approach to the task was logical. 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 very well structured and written in a coherent and logical way. The report was presented in a professional manner using appropriate language and formatting, good diagrams in appropriate places, good sentence/paragraph structure and clear calculations

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