

PSDE5014-Assignment_1

by Emyr Dyer

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HND Electrical & Electronic Engineering

Signals and Modulation

PSDE5014 – Signals and Digital
Communications

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1 INTRODUCTION, AIMS AND OBJECTIVES

The Aim of this Investigation is to examine the characteristics of AM, FM, and Digital Radio. There will also be simulated (calculated) and practical investigation of the functionality of FM signals.

2 RESEARCH INTO RADIO SYSTEMS

2.1 DISCOVERY

The history of Radio dates back as far as the 19th Century when Scottish scientist James Clerk Maxwell delivered a presentation in 1864 (published a year after), where he showed Mathematical evidence regarding Electromagnetism that Light had wave characteristics. Later, between 1886 and 1888, German physicist Heinrich Hertz proved Maxwell's Mathematical proof of the wave characteristic using the frequency known now as the Radio Spectrum by transmitting Electromagnetic Waves, and after publishing the results of his experiments, the Radio Waves were popularly referred to as 'Hertzian Waves'. Later, in 1894, Professor Oliver Lodge experimented with Wireless Signals using Hertz's Waves with a receiving unit set up in his Lecture Theatre which picked up Radio Signals received from a nearby building. Developing Lodge's work further, Bengali physicist Jagadish Chandra Bose concluded that the Radio Spectrum or 'Invisible Light' was able to pass through most obstacles, implying the benefit of eliminating the use of transmitting wires, and in the next year Bose developed a device called a 'Coherer' which was effectively a receiver. Soon after, Russian physicist Alexander Stepanovich Popov, used a Coherer in the construction of a Radio Receiver which was again developed further into a Lightning Detector. Also in 1895, Italian inventor Guglielmo Marconi had after some research on Hertzian Waves, developed the first viable portable Transmitters and Receivers which could transmit as far as half a mile, which was then extended to nearly two miles when elevating the antennae and grounding the units (Garratt, 1994).

2.2 EFFECTS ON THE WORLD

In 1896, Marconi established a patent for the 'Hertzian Wave Base Telegraphic System' which was notable for being credited with saving approximately 705 survivors of the Titanic disaster. The first individual to transmit their voice through wireless means was Brazilian priest Roberto Landell de Moura in 1900, which reached 5 miles, and in 1904 obtained three US patents for the Wave Transmitter, the Wireless Telephone, and the Wireless Telegraph. In 1906, Canadian Reginald Fessenden broadcast the first AM radio broadcast from Massachusetts which comprised of a reading from the Bible and violin performance of 'O Holy Night', which could be received by seafaring vessels (Coe, 1996).

Over the years, numerous developments were made to make Radio commercially viable for both broadcast of video and audio as well as two-way communication and in 1955, Sony developed the first transistorized radio which dramatically reduced the size of a Radio Receiver and only required a small battery (Sonorama, 1993).

Arguably the next most significant development of Radio technology which was the Global Positioning System which is today kept operational by the United States Air Force. A simple description of how GPS works is that the receiving GPS unit in line of sight with at least four satellites can determine the location and time where the unit is based on the signals received from those satellites (El-Rabbany, 2002).

2.3 TRANSMITTER/RECEIVER BLOCK DIAGRAM]

When deriving a Model or Block Diagram for AM Radio System, elements that must be considered include the Transmitter, the Receiver, and any Interfering Signals (of which there are a few).

The first step is to consider the AM signal:

$$X_C(t) = A_C[1 + \beta m(t)] \cos(2\pi f_C t) = A_C \cos(2\pi f_C t) + A_C \beta m(t) \cos(2\pi f_C t)$$

In the above equation, A_C is the Amplitude of the Carrier Signal, $m(t)$ is the Message Signal to be carried, f_C is the Frequency of the Carrier Signal and, β is the modulation index. By viewing $X_C(t)$ in the frequency domain, the two sidebands can be viewed as shown in Figure 2.1.

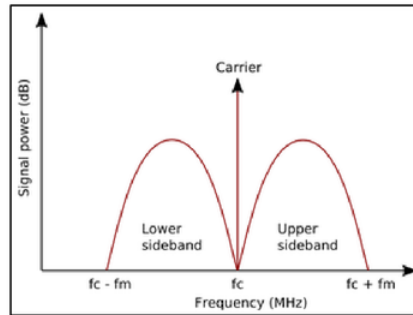


Figure 2.1

Looking at Figure 2.2, it is shown that the Original Audio Signal is used to form the envelope/ X_C (dotted line) that is filled by the carrier signal which itself is a higher frequency than the Original Signal, so that the original message can be carried over a greater distance. It should be noted that the Original Audio Signal is mirrored below the x axis of the new Signal.

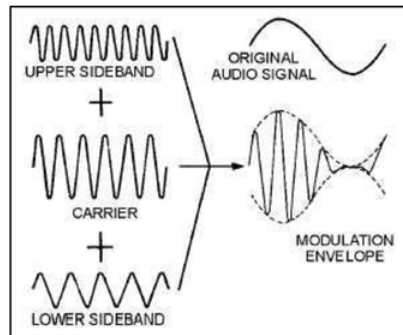


Figure 2.2

To retrieve the Original Audio Signal at the Receiver end, a low pass filter (Figure 2.3) is utilized to take away the carrier signal and leave behind the Original Audio Signal, which can then be outputted to an amplifier.

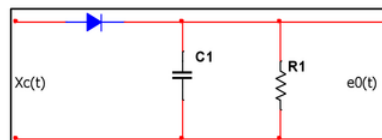


Figure 2.3

From these characteristics identified, the following System Block Diagram (Figure 2.4) is compiled that shows the Transmitter and Receiver end (Dixon, 1998).

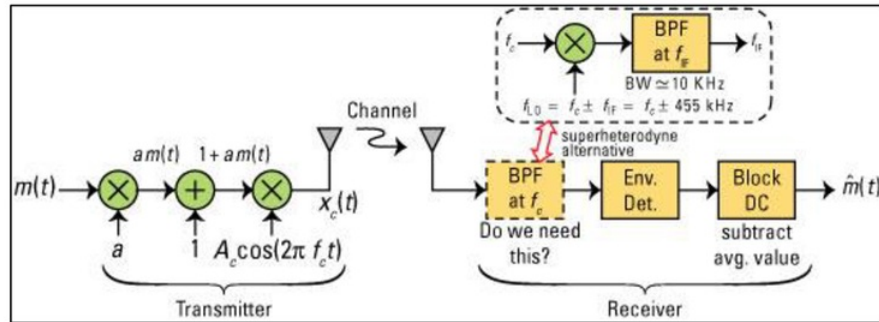


Figure 2.4

2.4 ADDITIONAL ANALOGUE MODULATION TECHNIQUES

Building on how Analogue Modulation works from the previous sub-section, there are other Analogue Modulation Techniques that can be utilised.

Double-Sideband Modulation (DSB) is the modulated output that has two sideband frequencies with the upper side band frequency being represented by an upper envelope and the lower side band frequency being represented by the lower envelope. To detect both side bands, a synchronous detector is used as opposed to the envelope detector in the case of basic AM.

Single-Sideband Modulation (SSB) is the modulated output where either one sideband or the other is utilized, not both. The reasoning for using this type of modulation is simply efficiency as power used to transmit can be less and the frequency is more efficiently used (Smillie, 1999).

2.5 DIGITAL RADIO DEVELOPMENT

Digital Audio Broadcasting (DAB) is the culmination of efforts since the 1980s to develop a means of Audio Transmission that was higher quality than AM and FM for commercial radio.

The means of carrying the Audio Data is based on the MPEG-1 Audio Layer II (MP2) codec, where the Audio is encoded digitally and transmitted over an Analogue Bandpass. The Source Audio produced by Radio Stations is in the form of Linear Pulse Code Modulation (LPCM) which effectively has a bit rate of 1.536×10^6 bit per second is re-modulated to Quadrature Phase Shift Keying (QPSK) which transmits bits of 00,01,10, and 11 as opposed to just 0 and 1. QPSK represents the four bit values through phase shift angles listed in Table 2.1 and demonstrated in **Error! Reference source not found..** To handle the conversion from LPCM to QPSK, the MP2 codec is used to drop the bitrate of the source audio down (Kalivas, 2009).

Bit Symbol	Degree Phase Shift
11	45
00	135
01	225
10	315

Table 2.1

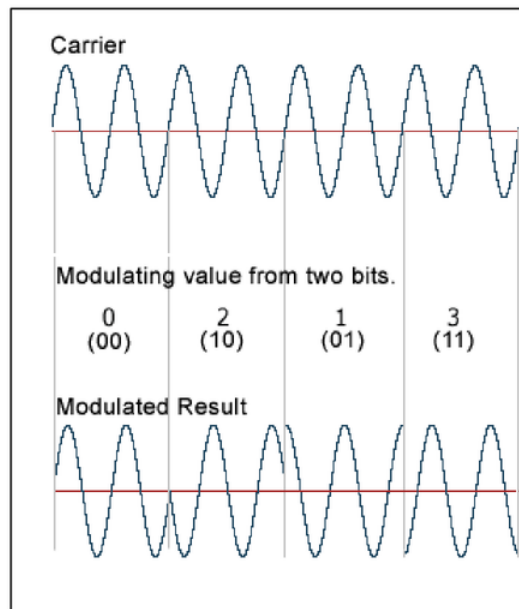


Figure 2.5

Other forms of modern Digital Radio Communication also exist in the form of Wi-Fi and Bluetooth. Wi-Fi typically uses 2.4GHz and 5GHz in modern applications such as domestic use. The 2.4GHz frequency used for Wi-Fi can be problematic in domestic use as microwaves and other Bluetooth Devices can introduce interference due to their own frequencies, however 5GHz frequencies tend not to experience this issue, with that said the 2.4GHz frequency tends to have a greater range for Wi-Fi. Bluetooth operates similarly on the 2.4 to 2.485 GHz range and is considered the lower power option of connecting Network Devices, however Bluetooth due to the low power design has a much shorter range of typically around 10 meters (Houda Labiod, 2007).

3 EXPERIMENTAL METHOD

An experiment to evaluate the performance of Frequency Modulation was carried out using the following specifications:

- A Carrier Frequency (f_c) of 455kHz with an amplitude (E_c) of 375mV,
- A Frequency Modulation (f_s) of 10kHz with a square wave of 1.5V amplitude, and
- The Carrier wave must vary between 425kHz and 485kHz.

Before carrying out the experiment, calculations were carried out to produce a predictive comparison to measured results.

$$\text{Modulation Index, } \beta = \frac{f_{c(MAX)} - F_c}{f_s} = \frac{485 \times 10^3 - 455 \times 10^3}{10 \times 10^3} = 3$$

$$\text{Frequency Deviation, } \Delta f = \beta \times f_s = 3 \times (10 \times 10^3) = 30\text{kHz}$$

With the Modulation Index identified, a Bessel Table was consulted to perform the following calculations using $J = \beta \times E_c$:

$$@ 455\text{kHz } J_0 = 0.26 \times (375 \times 10^{-3}) = 97.5 \times 10^{-3}V$$

$$@ 445 \& 465\text{kHz } J_1 = 0.34 \times (375 \times 10^{-3}) = 127.5 \times 10^{-3}V$$

$$@ 435 \& 475\text{kHz } J_2 = 0.49 \times (375 \times 10^{-3}) = 183.75 \times 10^{-3}V$$

$$@ 425 \& 485\text{kHz } J_3 = 0.31 \times (375 \times 10^{-3}) = 116.25 \times 10^{-3}V$$

$$@ 415 \& 495\text{kHz } J_4 = 0.13 \times (375 \times 10^{-3}) = 48.75 \times 10^{-3}V$$

$$@ 405 \& 505\text{kHz } J_5 = 0.04 \times (375 \times 10^{-3}) = 15 \times 10^{-3}V$$

$$@ 395 \& 515\text{kHz } J_6 = 0.26 \times (375 \times 10^{-3}) = 3.75 \times 10^{-3}V$$

From the calculated values, the following Spectrum Sketch was produced as Figure 3.1.

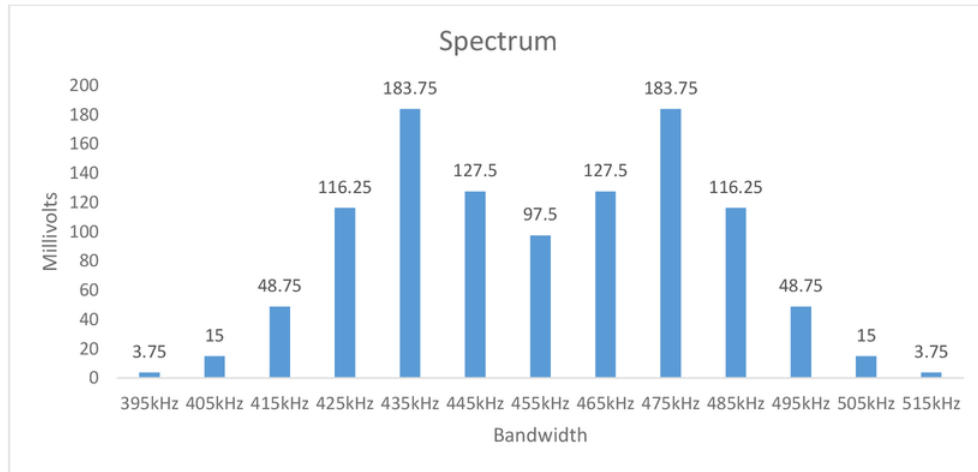


Figure 3.1

What can be observed is that as β gets greater, the number of sidebands is greater.

4 TESTING AND RESULTS

After getting some predicted results, the Practical Activity was carried out using a Signal Source, a Picoscope, a Power Supply, and a Signal Generator.

After configuration and powering up the setup, the frequency control was set to 455kHz and the modulation generator set to 6Vp-p at 1Hz. The readings showed that there was a carrier frequency deviation of 102kHz, but the carrier frequency was steady at 455kHz.

When reducing the Modulation in 1V steps, the frequency deviation dropped.

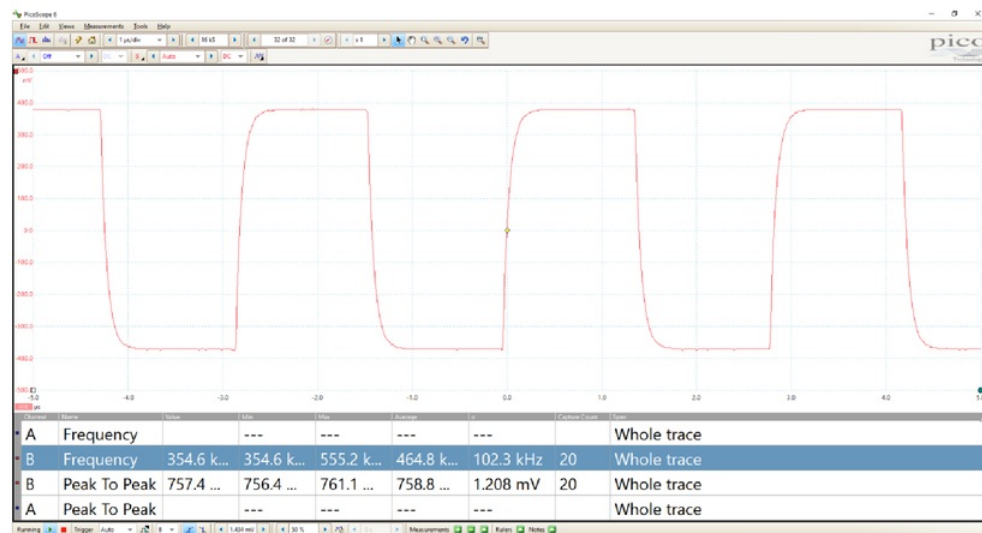


Figure 4.1: Ramping Voltage down. At 6V p-p.

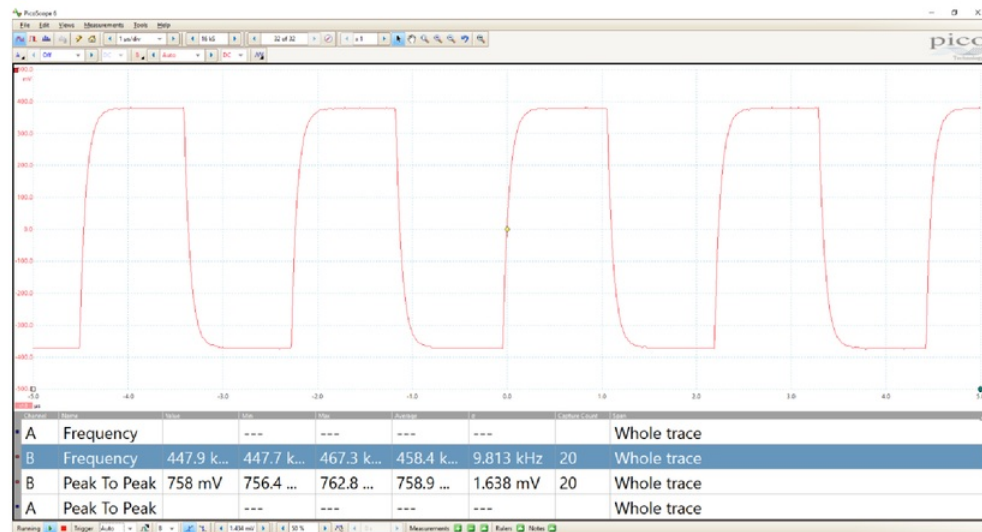


Figure 4.2: Voltage Ramped down to as close to 0V as possible

To verify the relationship, the Modulation source was set back to 6Vp-p and frequency deviation adjusted on the Signal Source until it was 60Hz.

The Modulation was then dropped in 2V stages and frequency deviation observed. It was difficult to detect the rate of change of the carrier frequency when adjusting the message frequency. At each 2V step, the frequency deviation was recorded into Table 4.1.

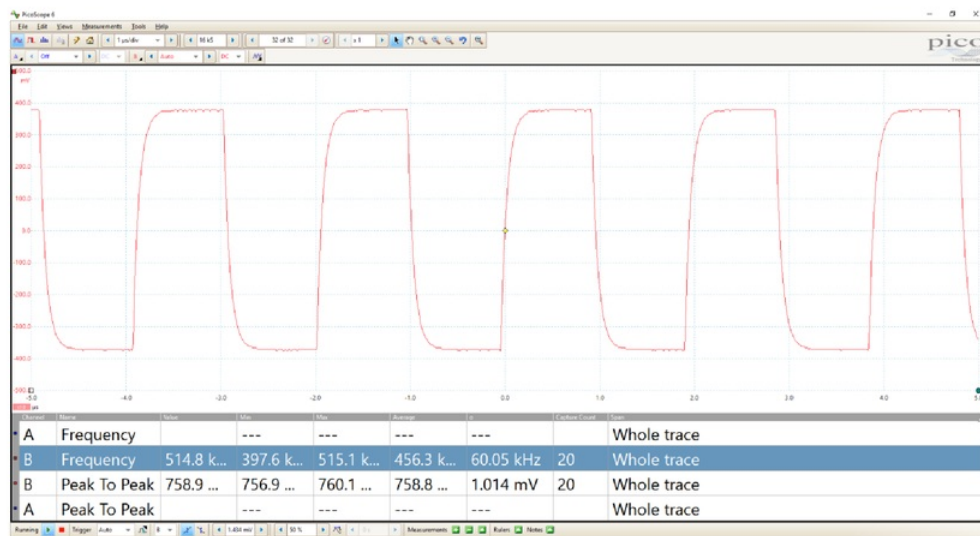


Figure 4.3

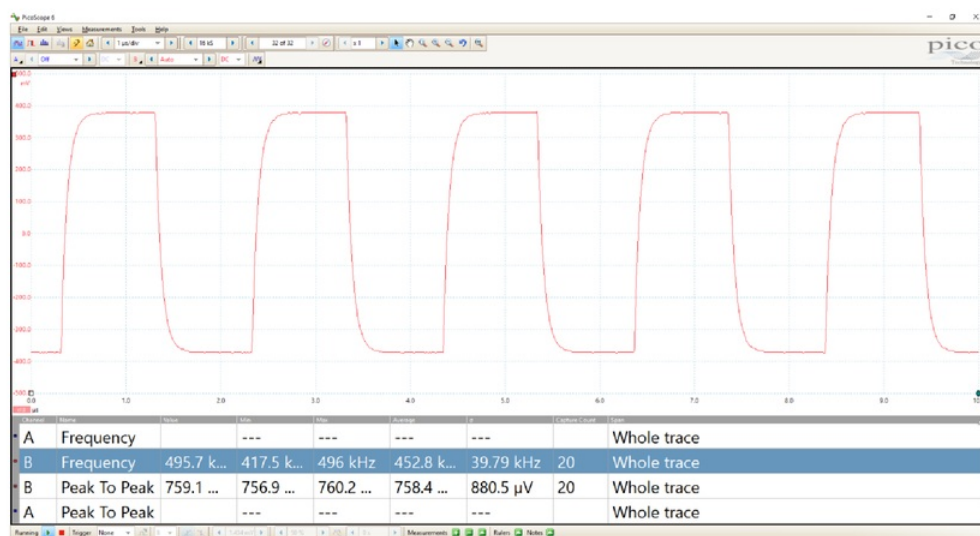


Figure 4.4

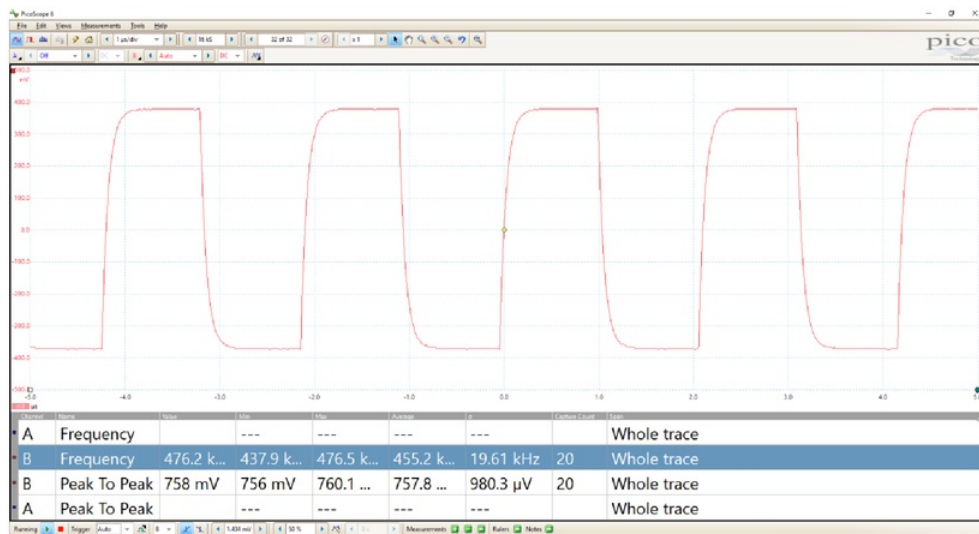


Figure 4.5

The next step was to observe the side frequencies using the Picoscope in Spectrum Analyser mode. With the attenuator set to 0dB, shots were taken and observed on 455kHz at the previously defined Voltage levels.

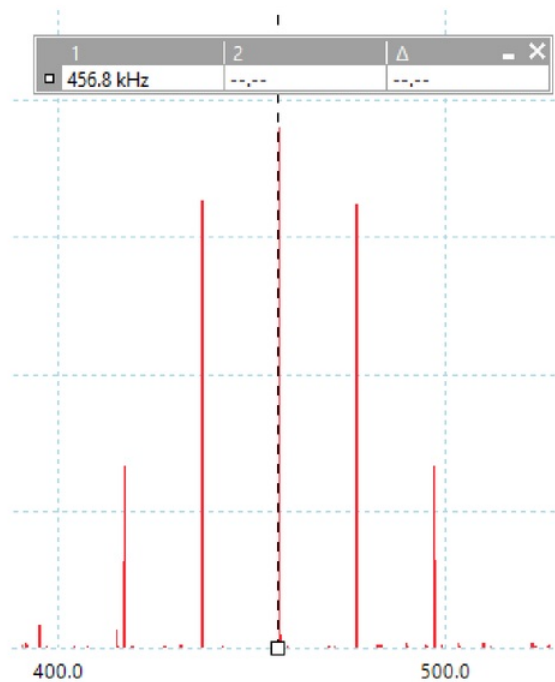


Figure 4.6: Zoom on 455kHz @ 2V p-p

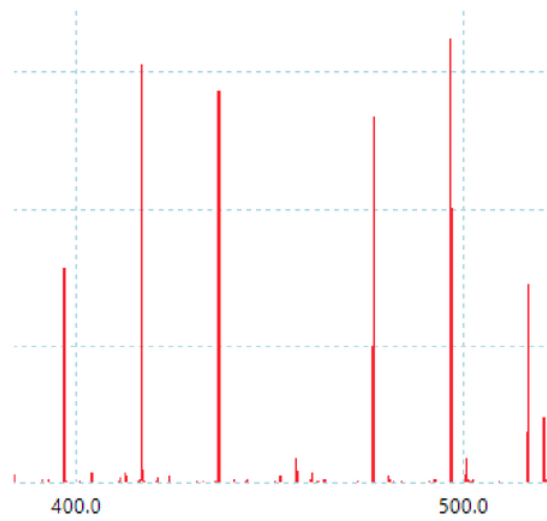


Figure 4.7: Zoom on 455kHz @ 4V p-p

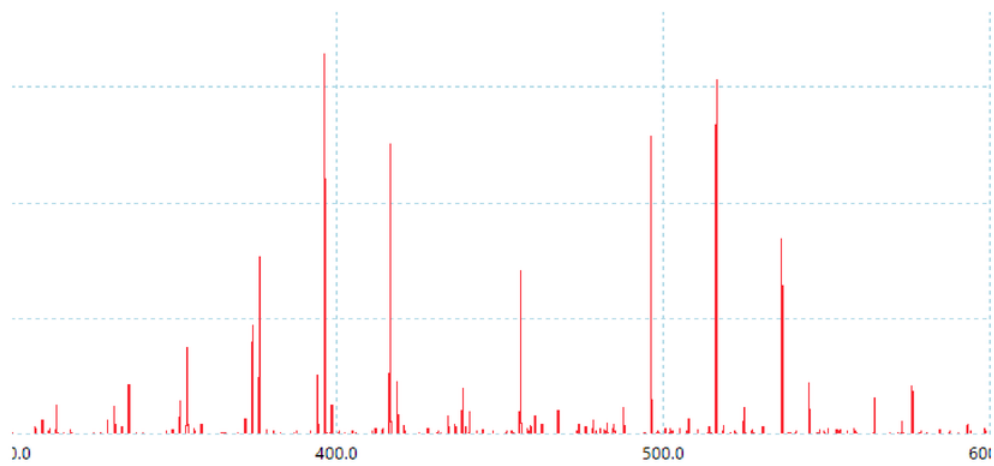


Figure 4.8: Zoom on 455kHz @ 6V p-p

Signal Frequency (Hz)	Voltage	Frequency Deviation (kHz)	Deviation Ratio	No. of Side Frequency Pairs
20	2	20	1	2
20	4	40	2	3
20	6	60	3	3

Table 4.1

What could be observed throughout the table completion process was that the Deviation Ratio was consistently proportional to the p-p Voltage levels.

5 CONCLUSIONS

The calculated predictions and the practical results showed great promise especially when comparing the sketched Spectrum Chart and the Measured Spectrum Analysis as they looked remarkably similar. The properties shown of FM give the impression that it is still a very effective means of transmitting signals with little distortion in comparison to AM. The performance of FM is still impressive considering the development of Digital Radio, while more complex and flexible, FM still has potential until the frequencies reserved are used in other Radio applications.

6 CITATION LIST

Coe, L., 1996. *Wireless Radio: A Brief History*. London: McFarland.

Dixon, R., 1998. *Radio Receiver Design*. Boca Raton: CRC Press.

El-Rabbany, A., 2002. *Introduction to GPS: The Global Positioning System*. Norwood: Artech House.

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Kalivas, G., 2009. *Digital Radio System Design*. New Jersey: John Wiley & Sons.

Smillie, G., 1999. *Analogue and Digital Communication Techniques*. Amsterdam: Elsevier.

Sonorama, A., 1993. *Sony Design: 1950-1992*. Tokyo: Asahi Sonorama.

7 IMAGE SOURCES

Figure 2.1	https://upload.wikimedia.org/wikipedia/commons/thumb/f/fd/Am-sidebands.png/300px-Am-sidebands.png
Figure 2.2	https://i.stack.imgur.com/SA9tr.jpg
Figure 2.3	Self-generated in Multisim
Figure 2.4	http://d2r5da613aq50s.cloudfront.net/wp-content/uploads/379613.image5.jpg
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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

54/100

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GRADING FORM: CSG-RUBIC

RESEARCH-INFORMED LITERATURE

 There was some evidence of further reading and research from credible and reliable sources. Your interpretation and understanding of the additional research was good and demonstrated an underlying appreciation of the subject. Your references still rely on a small selection of sources and you need to include more in-text references, especially for diagrams.

5

KNOWLEDGE AND UNDERSTANDING

 The knowledge and understanding of the subject demonstrated by this assignment was generally satisfactory. However the report lacked a lot of the required detail and there were some gaps in your knowledge of the basic principles. Additionally, your understanding of the higher level concepts was not shown. Further work - Explanations need to be written in much more detail and written in a more logical and clearer way. You didn't really explain how FM works and what the graphs meant.

18

ANALYSIS

 Your analysis of the task was brief and lacked a lot of the required detail. You have demonstrated reasonable analytical skills and your approach to the task was logical. You carried out a reasonable

9

evaluation of the results, but the conclusions were very brief. You needed to compare your practical results with the calculated results in much more detail.

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task were generally OK, you used the resources available 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.

18

SKILLS FOR PROFESSIONAL PRAC.



Your written report was generally well presented and contained most of the required detail, it was also written in a coherent and logical way. There were still some grammatical errors and you should proof read your work more thoroughly. Avoid using capital letters in the middle of sentences unless it is a proper noun.

4