1 AM Radio Reception

1.1 Chapter 3: Modulated Waveforms - Amplitude Modulation

Notes AM Modulation in a Nutshell:

A high frequency "carrier" wave f_c transports a lower frequency "program" content f_p, i.e., for a simple sinusoidal carrier wave the modulated signal is given by

$$V(t) = [A(1 + \alpha \cos(2\pi f_p t))] \cos(2\pi f_c t)$$

where $\alpha < 1$ is the modulation index. We can pretend that $[\,] = A(\,)$ is equivalent to the amplitude of the modulated waveform, so this makes the amplitude vary over time between $A(1-\alpha)$ and $A(1+\alpha)$. With some trig identities, we can rewrite this as

$$V(t) = A\cos(2\pi f_c t) + \frac{A\alpha}{2}\cos(2\pi(f_c + f_p)t) + \frac{A\alpha}{2}\cos(2\pi(f_c - f_p)t)$$

Thus the sum of three sinusodial waves with frequencies f_c, $f_c + f_p$, and $f_c - f_p$—i.e., the information content of an AM signal is contained within the sidebands of the carrier wave in the frequency domain.

Exploration

- Carrier: 770 internal source—50 kHz, 1 V → Multipler module (MULT) input A
- Program: 33500B—2 kHz, 5 V → SUMMER module input B
- DC VOLTAGE module 5 V → SUMMER input A
- SUMMER output → MULT input B
- MULT output → scope & 770

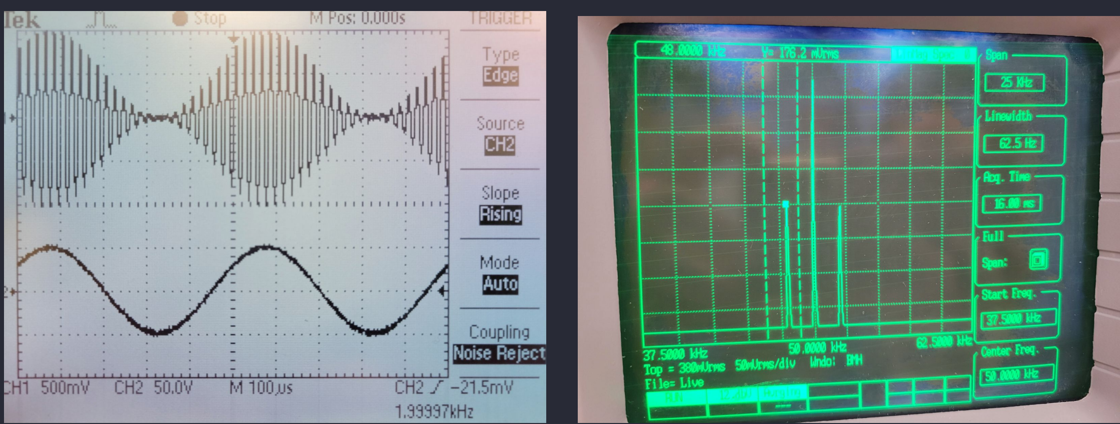

Figure 1.1: Scope (left) with bottom program content and 770 (right) view of AM Modulation of a 50 kHz carrier wave with a 2 kHz program wave.

In Figure 1.1, we see the scope and 770 view of the AM modulation of a 50 kHz carrier wave with a 2 kHz program wave. The scope view shows familiar looking AM modulated waveform, while the 770 clearly shows the carrier frequency at the center and the two sidebands which dictate the frequency of the program content.

Changing content of the two waves

- Increase frequency of program content:
  - The sidebands move further away from the carrier frequency just as the theory predicts $f_c \pm f_p$.

- Change carrier frequency:
  - Moves the 3 peak structure left or right (low freq and high freq respectively) on the 770 (Figure 1.2).
  - The envelope of the modulated waveform remains the same, but the inside oscillations increase as f_c increases.

Figure 1.2: Increasing (right) and decreasing (left) program frequency.

- Program amplitude:
  - Increasing the program amplitude increases the amplitude of the sidebands independent of the carrier amplitude (Fig. 1.3).

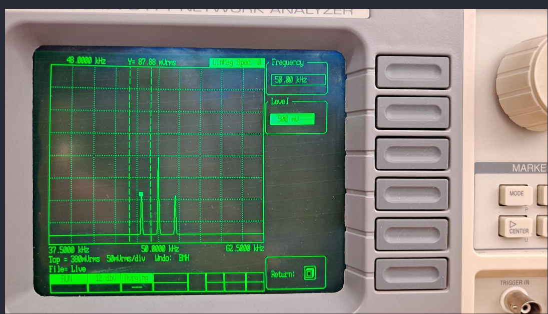

Figure 1.3: Decreasing program amplitude.

- Carrier amplitude:
  - Increasing the carrier amplitude increases the amplitude of the carrier wave independent of the program amplitude (Fig. 1.4).

Figure 1.4: Increasing (right) and decreasing (left) carrier frequency.

- Program content to square wave:
  - There are multiple sidebands at odd multiples of the program frequency.

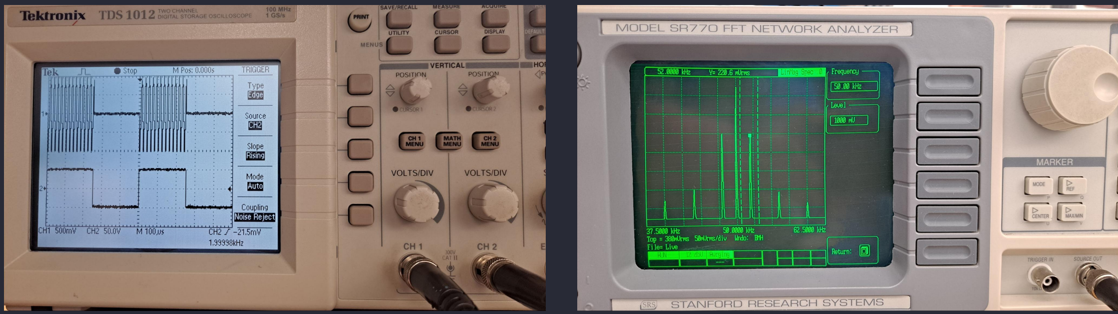

Figure 1.5: Scope (left) with program content in the bottom and 770 (right) view of AM Modulation of a 50 kHz carrier wave with a 2 kHz square wave program wave.

Why $\alpha < 1$? The multiplier ouputs a scaled product of the two input signals

$$V_{\text{out}} = \frac{V_A V_B}{10}$$

for inputs with voltage ± 10 V, and frequency lower than 1 MHz. Thus for 5 V DC input from the summer with the program signal gives

$$\begin{aligned} V_{\text{out}} &= (5V + P\cos(2\pi f_p t))(A\cos(2\pi f_c t))/10 \\ &= \frac{5A}{10} V \left(1 + \frac{P}{5V}\cos(2\pi f_p t)()\right)\cos(2\pi f_c t) \end{aligned}$$

So the waveform has a modulation index $\alpha = \frac{P}{5V}$. In our first case (Fig. 1.1), $P = 5V$ so $\alpha = 1$, Here the scope clearly shows the two distinct frequencies that make up the AM waveform—i.e., the envelope matches the program content shown simultaneously below, and the carrier frequency is resolved in the small oscillations within the envelope.

When we increase $\alpha \to 2$ (Fig. ref here), the program content is overmodulated or *distorted* which makes it hard to extract out the program content from the modulated waveform.

Chapter 11: AM Radio Reception

Notes

- Since AM radio signals are roughly 540-1600 kHz, i.e., 500-200 m wavelength, the EM waves are pretty uniform and can be received by our simple electrical wire antenna connected to an LC-resonant circuit.
- The LC-resonant slighly tunes the frequency range into a narrow band of frequencies, which can be changed by adjusting the number of inductors we put in series (Fig. 1.7).
- Downcoversion: Before we narrow the frequency search range, we can first use downconversion to bring the high frequency AM signals to a lower frequency range provided by the High-Frequency (HF) Mixer module.
  - Local-oscillator (LO) source: Using the 33500B, we set the LO frequency so that the difference between the LO and the AM signal is in the range of our 770 (100 kHz). e.g., for target radio station (RF) 850 kHz, setting the LO to 770 or 930 kHz will output a 80 kHz difference frequency from the HF mixer. It will also ouput and sum & difference frequencies from other radio stations which we must filter with the IF output.
  - IF Filter: To create a fixed pass band that only allows the a narrow range of difference frequencies to pass through.

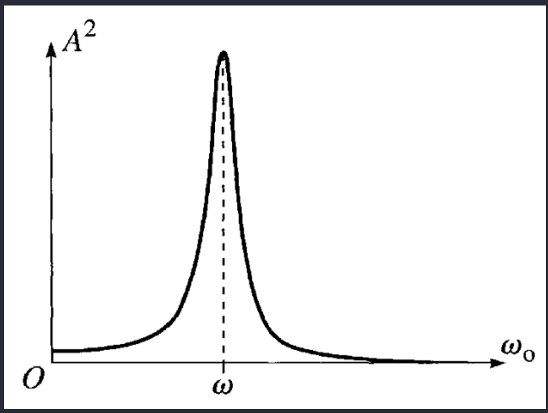

Figure 1.6: Resonant frequency of RLC circuit (Taylor, Classical Mechanics). Our circuit has a broad resonance (rather than sharp) which will receive a band full of AM stations.

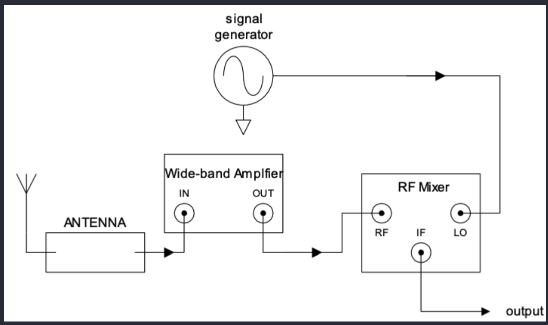

Figure 1.7: AM Radio Reception setup.

Experiment: Finding Radio Stations

- First note a near by radio station we can pick up from St. Louis (Radio Station List). e.g. KFUO 850 kHz.
- Set three inductors in series on the radio antenna circuit
- Radio antenna circuit OUPUT → Wideband Amp (10x) or until the signal is visible on the scope
- Wideband Amp OUTPUT → HF Mixer INPUT RF
- 33500B 0.7 to 1.1 V with difference frequency of 80 kHz OUTPUT → HF Mixer INPUT LO
- IF OUT → Filter Module 80 kHz; 8 Gain
- Filter OUT → scope & 770 and note the visualized signal
- Tune the LO frequency to get a strong signal
- De-modulate the signal by tuning the LO frequency *exactly* to the Radio station frequency (carrier freq) tjnhe zero beat frequency, e.g.,