

STUDIES OF POLICE RADAR

by

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ABSTRACT

The intent of this thesis was to do a study of continuous wave radar systems. These are the radars which determine a targets speed. I focused my work on the radar gun, which is currently employed by police forces to catch speeders.

I conducted tests on the receiver sensitvity of the radar gun. I built an audio amplifier circuit for the signals received by the radar, so that in addition to seeing these signals on an oscilloscope, I was able to hear them. I then took the radar gun, the audio amplifier and a portable cassette tape recorder onto Memorial Drive. There I recorded some signals of the traffic.

From the tests, data, tape recordings and other information, I have concluded that under ideal conditions, that is target at zero angle with the radar gun, no other targets in the radar area and no mechanical or radio interference, the radar will make an accurate reading. However, if all these conditions are not met, then the radar will not be accurate enough to cast no shadow of doubt.

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GOAL OF THESIS

Have you ever been stopped by a police officer and he said to you that you were clocked by the radar gun to be going at such a speed and that the speed limit was only so much? If you were indeed going at such a speed, you would take whatever he gave you, without questions. Even if you were not going at such a speed, you still would not question him, because it is almost impossible to fight him. With this thesis, I will try to raise some questions, questions as to whether his radar is accurate all the time, when is it not and under what conditions.

BASIC PRINCIPLE OF RADAR

The radar unit which I worked with had a transmitter which operated on the X-band or a frequency of 1.0525×10^{10} hertz, which is 10.525 gigahertz. The transmitter of the radar sends out a sinusoidal signal. When this signal reflects off a moving target, the reflected signal's frequency is shifted proportional to the target speed according to the Doppler shift principle.

$$\text{shift in frequency } f_d = \frac{2 f_o v}{c}$$

f_o : the transmitter frequency - 10.525 gigahertz

v : target speed

c : speed of light

$$\begin{aligned} f_d &= \frac{2 (1.0525 \times 10^{10} \text{ hertz}) v}{186000 \text{ miles/second}} \\ &= \frac{2.105 \times 10^{10} \text{ hertz}}{(186000 \text{ miles/second}) (3600 \text{ seconds/hour})} v \end{aligned}$$

$$= \frac{31.4 \text{ hertz}}{\text{miles/hour}} v$$

If a target was moving at 10 miles/hour, the reflected signal would have its frequency shifted $\frac{31.4 \text{ hertz}}{\text{miles/hour}} 10 \text{ miles/hour}$ which equals 314 hertz.

Figure 1 shows the internal signal processing of the radar. The radar transmits and receives its signals through the same antenna. The transmitted and received signals also go through a comparator. Here the two signals are compared and the difference in frequency is sent to the amplifier. For all subsequent studies, the tests were conducted on this signal. When the signal is amplified to a certain level, it triggers the digital logic section. Here there is essentially a counter which counts the frequency and digital logic to convert the counted frequency to the corresponding miles per hour, which is then displayed on a digital reading.

Before the radar becomes operational, the operator is supposed to calibrate the radar with a tuning fork. The tuning fork modulates the transmitted signal so that the radar thinks that it is moving.

POSSIBLE SOURCES OF ERROR

Typically the antenna of the radar will radiate signals over a 15 degree angle. If the radar was a quarter of a mile away, it would cover the entire width of a four-lane

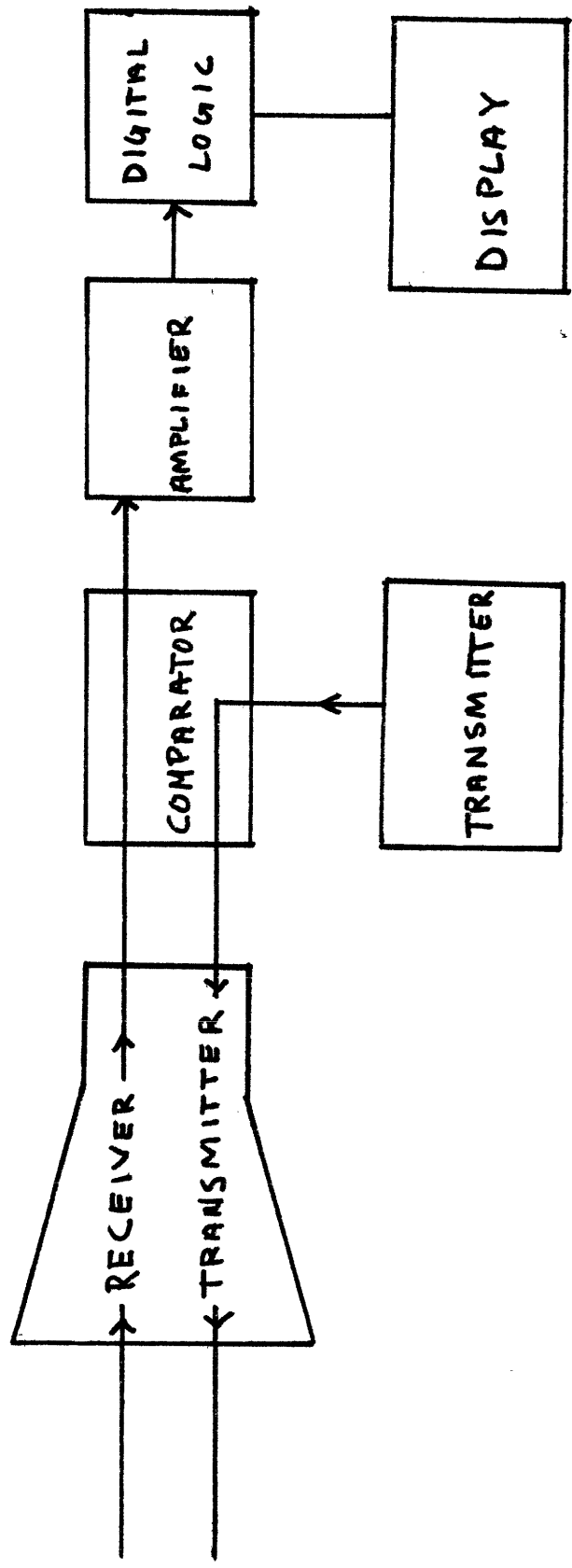


FIGURE 1. BLOCK DIAGRAM OF RADAR

highway. In this case the radar will not be able to pick one particular car (figure 2). The radar will usually lock onto the car with the strongest signal or with the highest speed. However the operator does not know which car the radar has locked onto. He can only guess by making a visual sighting.

Another source of error is cosine error. Figure 3 shows that only if the angle between the radar and the line of travel of the traffic is zero degrees, the radar will give an accurate speed reading. Any other angle will produce a discrepancy. The displayed speed is equal to the cosine of that angle times the actual speed.

RECEIVER SECTION OF RADAR

The percentage of transmitted signal which reflects off a target is very small, and the percentage of reflected signal which is received by the radar is even smaller. Therefore the radar has to be very sensitive to the reflected signal and block out all other signals.

Figure 4 shows the setup I used to test the sensitivity of the radar's receiver section. A microwave oscillator which is modulated by an audio oscillator set at 1570 hertz or 50 miles per hour, transmits a sinusoidal signal through a coaxial cable placed in front of the radar gun. With an

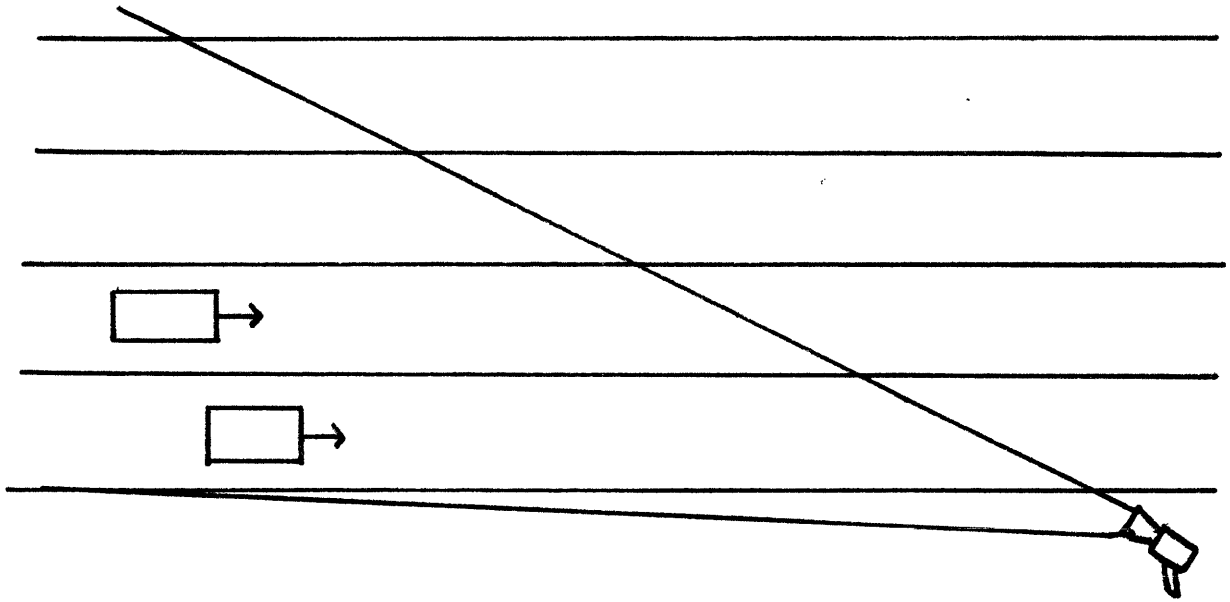
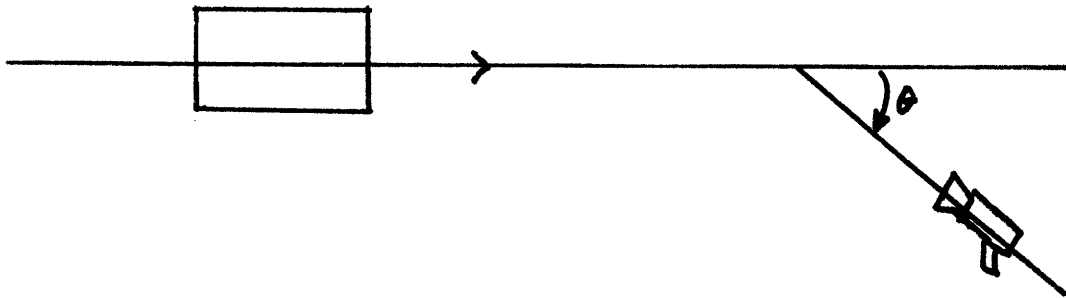


FIGURE 2. MULTIPLE TARGETS



SPEED DISPLAYED = $\cos \theta$ (ACTUAL SPEED)

FIGURE 3. COSINE ERROR

oscilloscope, I looked at the signal received by the radar. I took the signal at the point in the radar gun before it was amplified, so that I got the received signal before any processing.

Figure 5 is the curve that was obtained from this test. The vertical axis is the peak to peak voltage amplitude of the signal. The horizontal axis is the frequency swept by the microwave oscillator. The receiver is most sensitive at frequency 10.485 gigahertz (8 volts peak to peak). This is not the frequency the transmitter is rated at (10.525 gigahertz). This was probably due to the fact that the scale of the microwave oscillator from which the frequency was read was not correct.

AUDIO AMPLIFIER CIRCUIT

Having looked at the received signal through an oscilloscope, I could not determine the different frequencies in the signal. There were many signals of different frequencies superimposed on each other.

Another way to determine some of the different frequencies involved was to be able to hear the signal. This could be done because the frequencies of the signal are in the audio range (10 miles/hour = 314 hertz, 100 miles/hour = 3140 hertz).

A circuit diagram of the audio amplifier circuit is on figure 6. The main component is a National Semiconductor

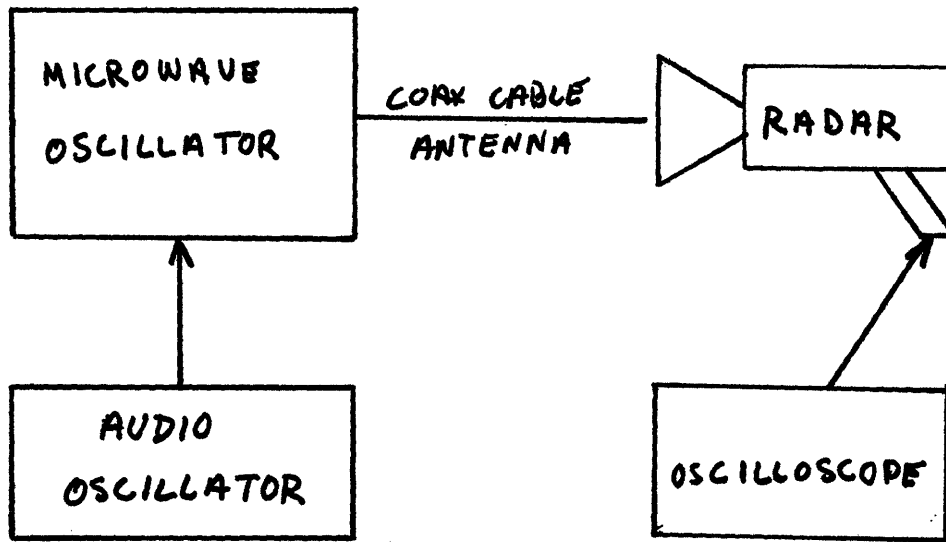


FIGURE 4. RECEIVER SENSITIVITY TEST SETUP

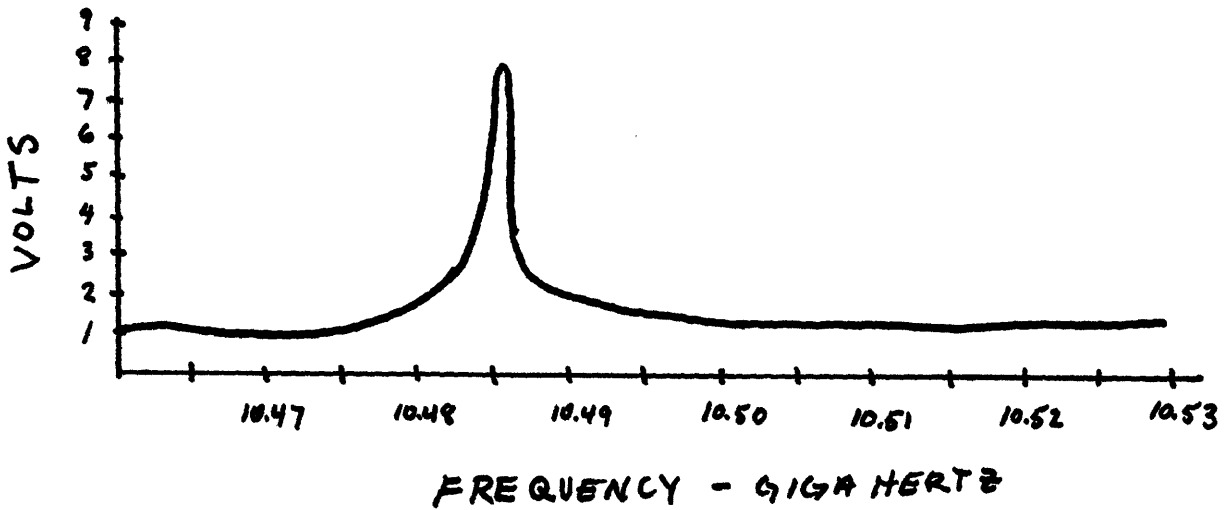


FIGURE 5. RECEIVER SENSITIVITY CURVE

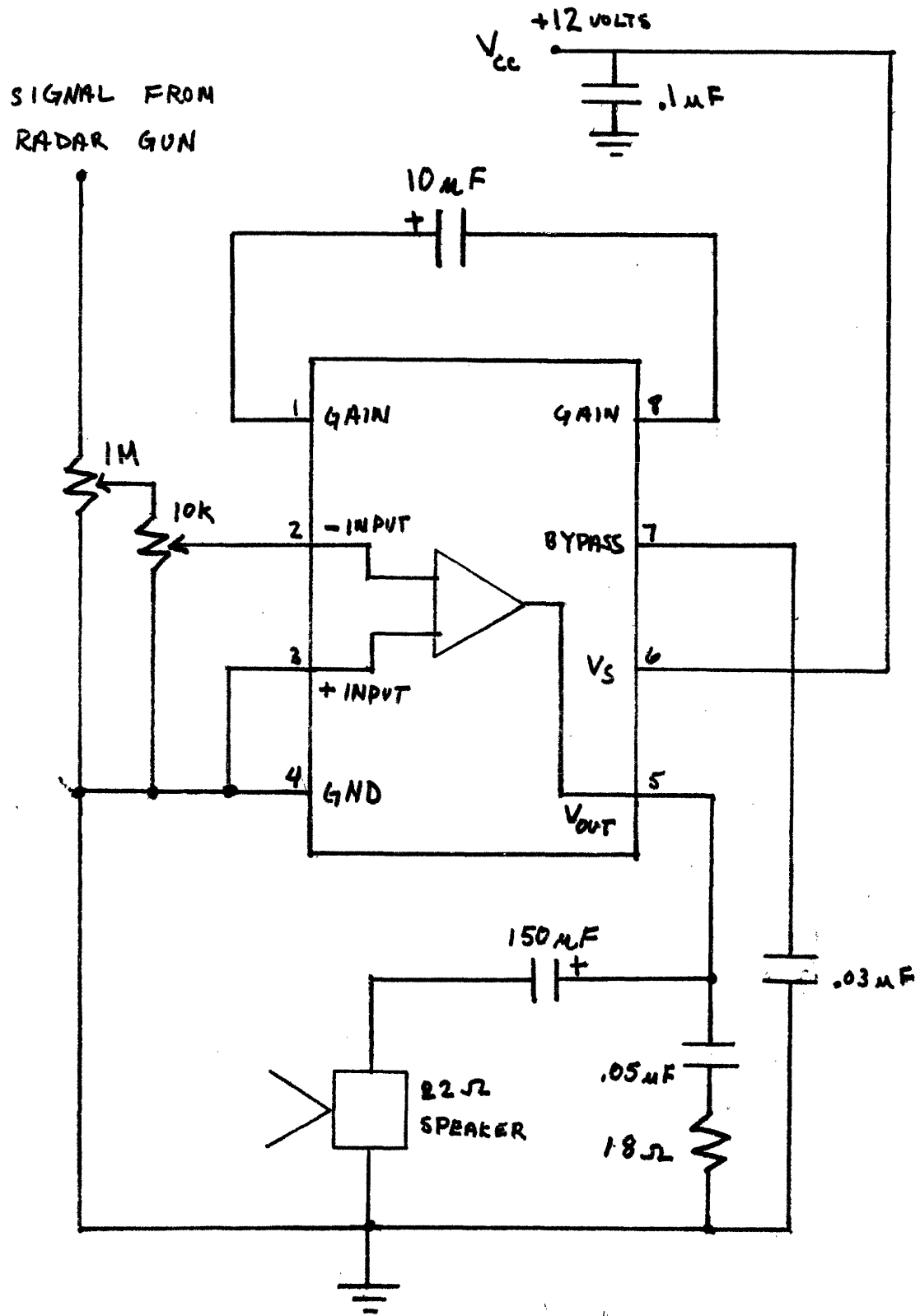


FIGURE 6. AUDIO AMPLIFIER CIRCUIT

LM 386 audio amplifier chip. All the capacitors and resistors were noncritical except for the 150 microfarad capacitor, which determines the low frequency cutoff of the circuit.

At half power output, the impedance of the low frequency cutoff capacitor equals the impedance of the speaker:

$$\frac{1}{c \text{ s}} = 22 \text{ ohms}$$

if I want a low frequency cutoff at 300 hertz or about 10 miles per hour

$$\frac{1}{c \text{ 300 hertz}} = 22 \text{ ohms}$$

$$c = \frac{1}{(300 \text{ hertz}) (22 \text{ ohms})}$$

$$c = 151.5 \text{ microfarads}$$

The 10 kilohm potentiometer is the volume control for the circuit.

The signal from the radar gun has a maximum peak to peak voltage of 8 volts, while the LM 386 audio amplifier chip has a maximum input voltage rated at .4 volts. Therefore the 1 megaohm potentiometer is used to reduce the signal. I could have used two resistors to act as a voltage divider instead of the potentiometer to restrict the signal, however there might be instances when the signal from the radar gun is very weak and I would like to have the capability to be able to hear a strong signal by not deamplifying the weak signal.

On figure 7 is the frequency response of the audio amplifier circuit. It turns out that its low frequency cutoff is not at 300 hertz, the calculated point, but at approximately 200 hertz. The calculation is only a crude method. This circuit will accurately reproduce a signal down to 200 hertz or about 7 miles per hour.

I wanted some way of recording the signals I heard through the audio amplifier. I decided to record the results using a portable cassette tape recorder. In order to make a good recording, I had to match the output of the audio amplifier circuit to the input of the tape recorder. I first had to conduct a test to obtain the response curve of the tape recorder (figure 8). I used a signal generator set at 1000 hertz as the input to the recorder. At certain voltage levels, from 0 to 1000 millivolts, I recorded these signals. I then played the tape to the corresponding input and with an oscilloscope, I read the output voltages.

To get the most accurate reproduction, I would want to stay in the linear range, from 0 to 200 millivolts.

The output of the audio amplifier circuit has a maximum output of 15 volts (supply voltage). I used a 100 ohm resistor and a 1 kilohm potentiometer between the output of the audio amplifier circuit and the input of the tape recorder. With the potentiometer, I would be able to control the volume level to the tape recorder.

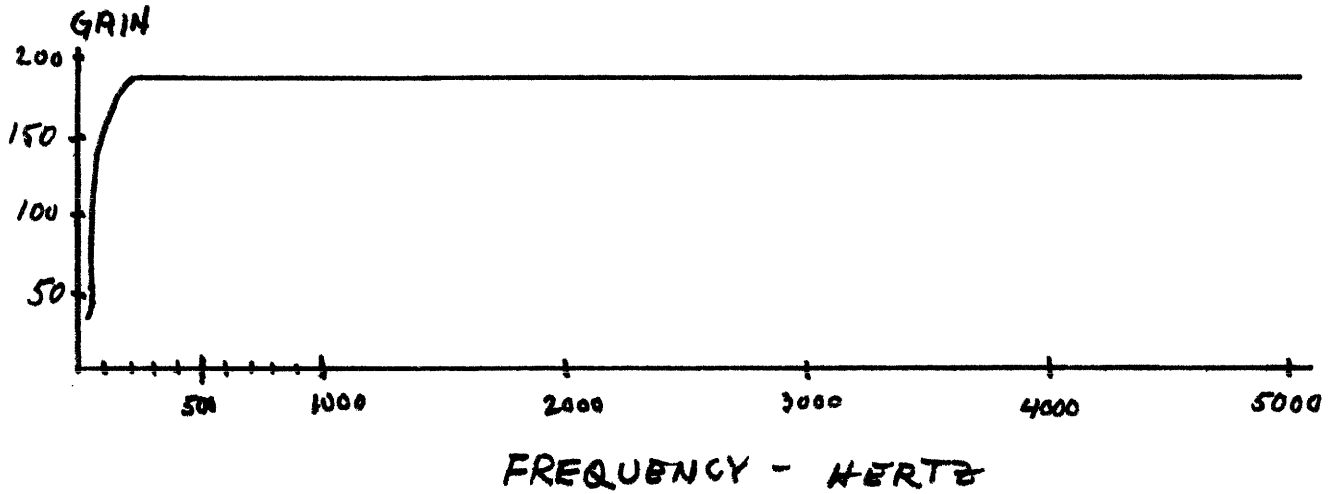


FIGURE 7. AUDIO AMPLIFIER FREQUENCY RESPONSE CURVE

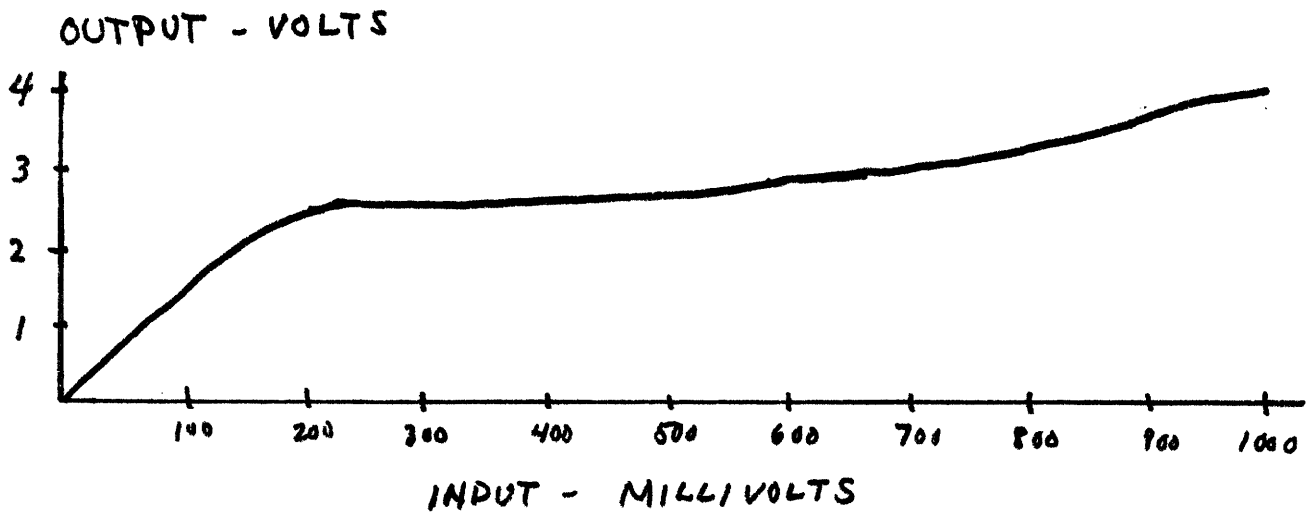


FIGURE 8. TAPE RECORDER RESPONSE CURVE

FIELD TEST

The field test was conducted on Memorial Drive in front of the sailing pavilion across from Walker Dining Hall at about 4 p.m. The tests were conducted with the radar gun in four different positions with respect to Memorial Drive and the traffic.

Figure 9 shows the different positions. A cassette tape recording was made at this time. At zero degrees and the traffic approaching, the signals on the tape had a constant tone and the volume increased with time. This would indicate that the cars were moving at a constant speed, and as the cars approached, the signal became stronger. At 45 degrees with the traffic approaching, the signal started very abruptly, and the duration was much shorter. This is due to the fact that the radar area is much smaller than in the zero degree case. At zero degrees and the traffic departing, the signals were constant and decreasing in volume. At 45 degrees with the traffic departing, the signals sounded very much like they did in the case of the traffic approaching, except that they too had a decreasing volume. In none of the cases were there only one clear signal for a long period of time. There were always other signals introduced.

CONCLUSIONS

From listening to the tape recorded signals, it is difficult for me to distinguish many of the signals. When

MEMORIAL DRIVE

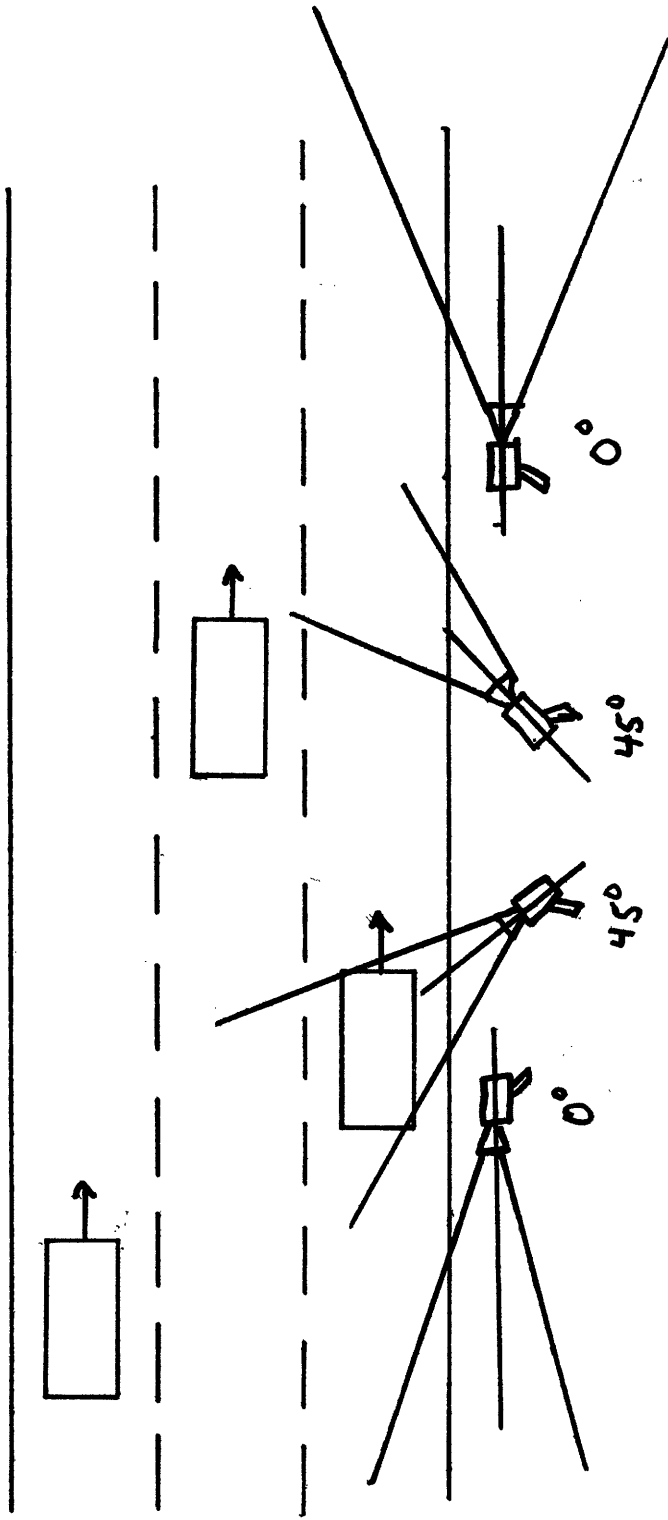


FIGURE 9. FIELD TEST ON MEMORIAL DRIVE

two cars are very close to each other and moving at about the same speed, the radar gun sees them as one target. Although if the two cars were more distinguishable, the radar gun is supposed to lock onto either the car giving the strongest signal or the car moving faster. However the operator does not know to which car the radar gun is reading.

Even though cosine error will help the motorist by always giving a lower speed reading, it is still an inaccuracy in the system.

There is always the possibility of interference in the area. Any transmissions at the radar's receiver frequency will mask the weak reflected signal. One of the simplest forms of mechanical interference is if the operator has his engine fan running. This could act like a tuning fork and give the radar a false reading.

Only if there is one car in the radar area, the car and the radar at a zero degree angle and no radio or mechanical interference, then the radar will make an accurate reading. Anything less than all these conditions, the radar will perform with inaccuracies.

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