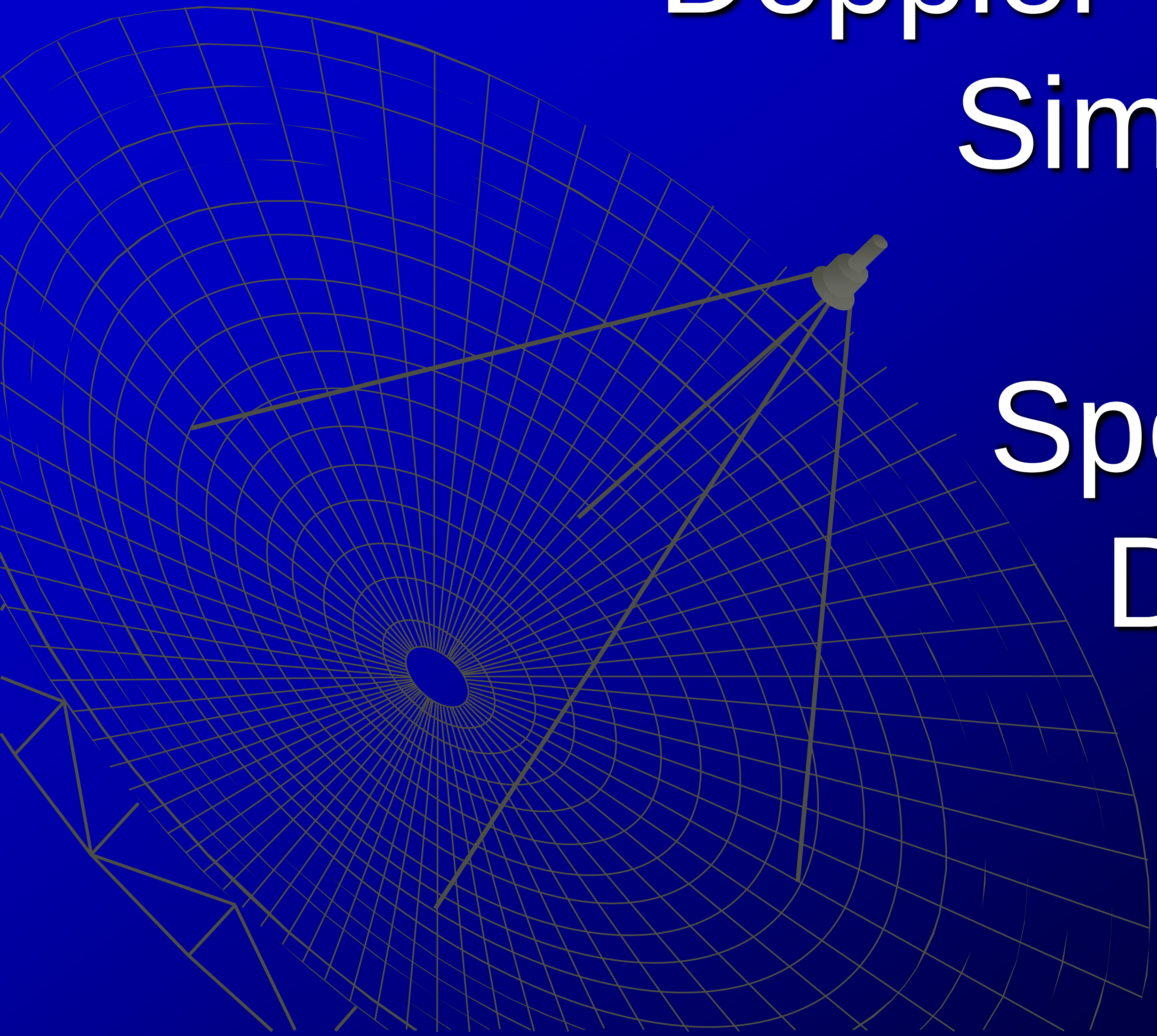
Doppler Radar Simulator

and

Spoofing Device



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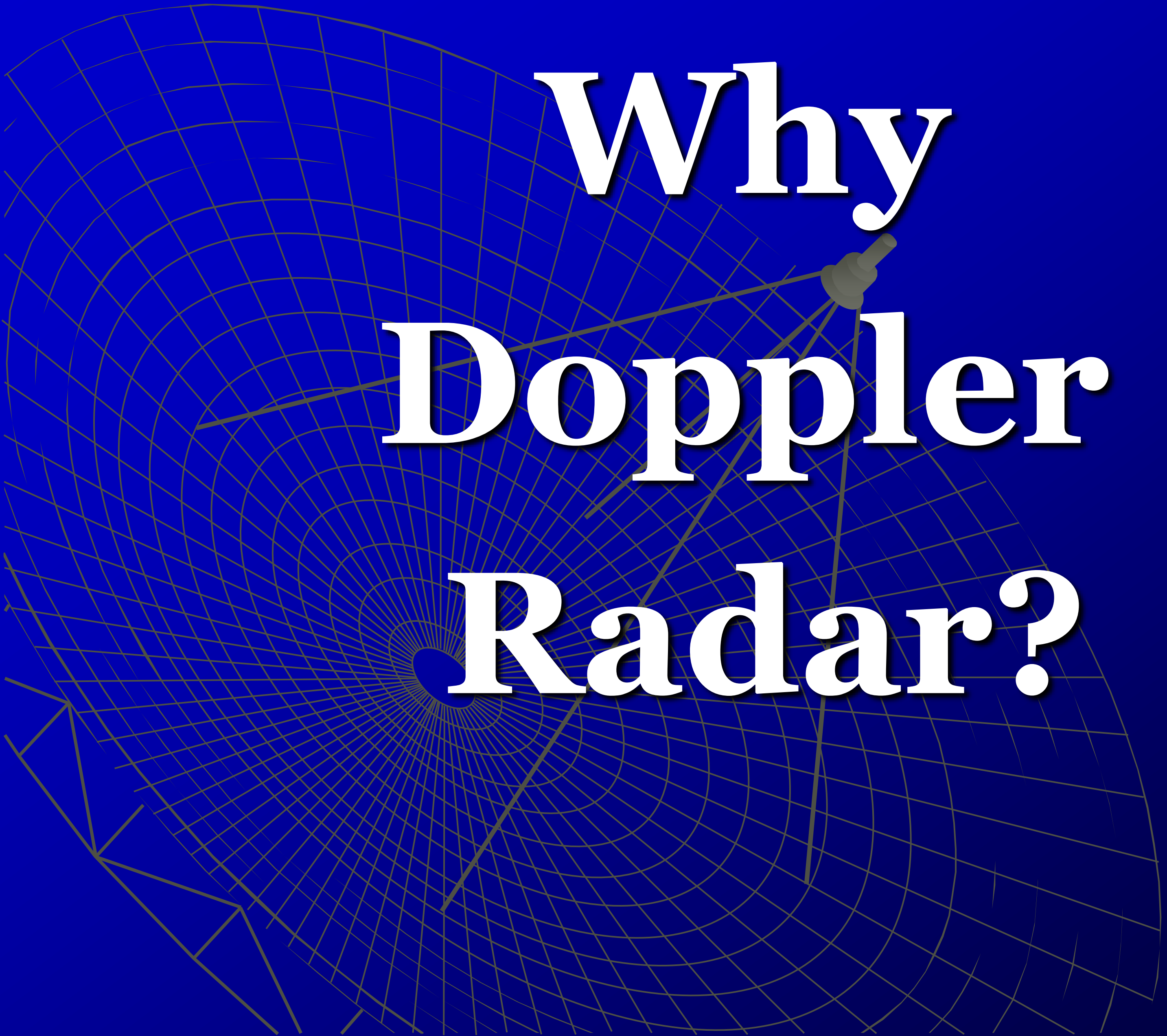
Why Doppler Radar?



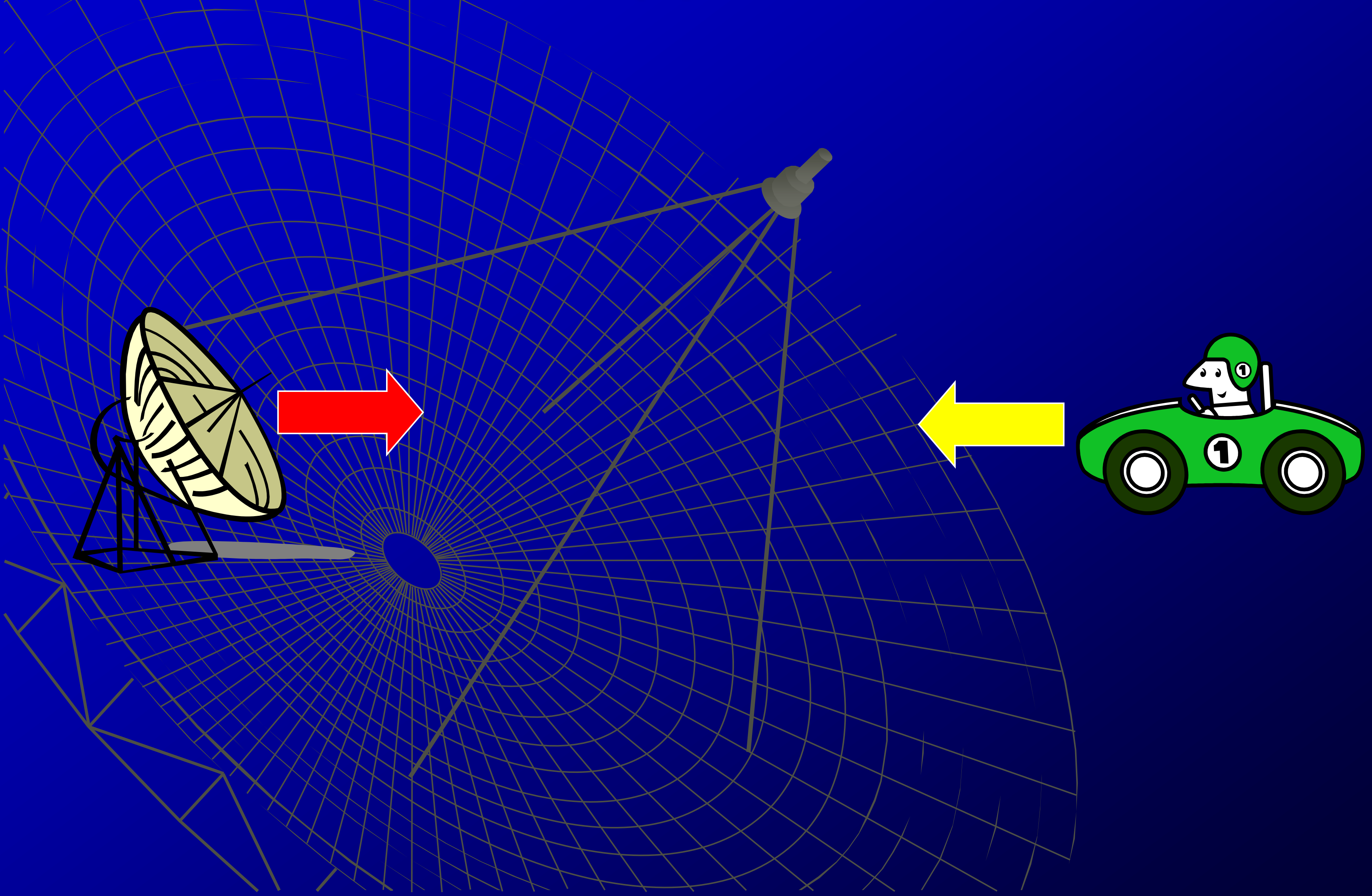
Project Breakdown

- Doppler Radar Simulator
  - Radar Unit
  - Computer Interface
- Spoofing Device
  - Spoofing Device
  - Test Vehicle

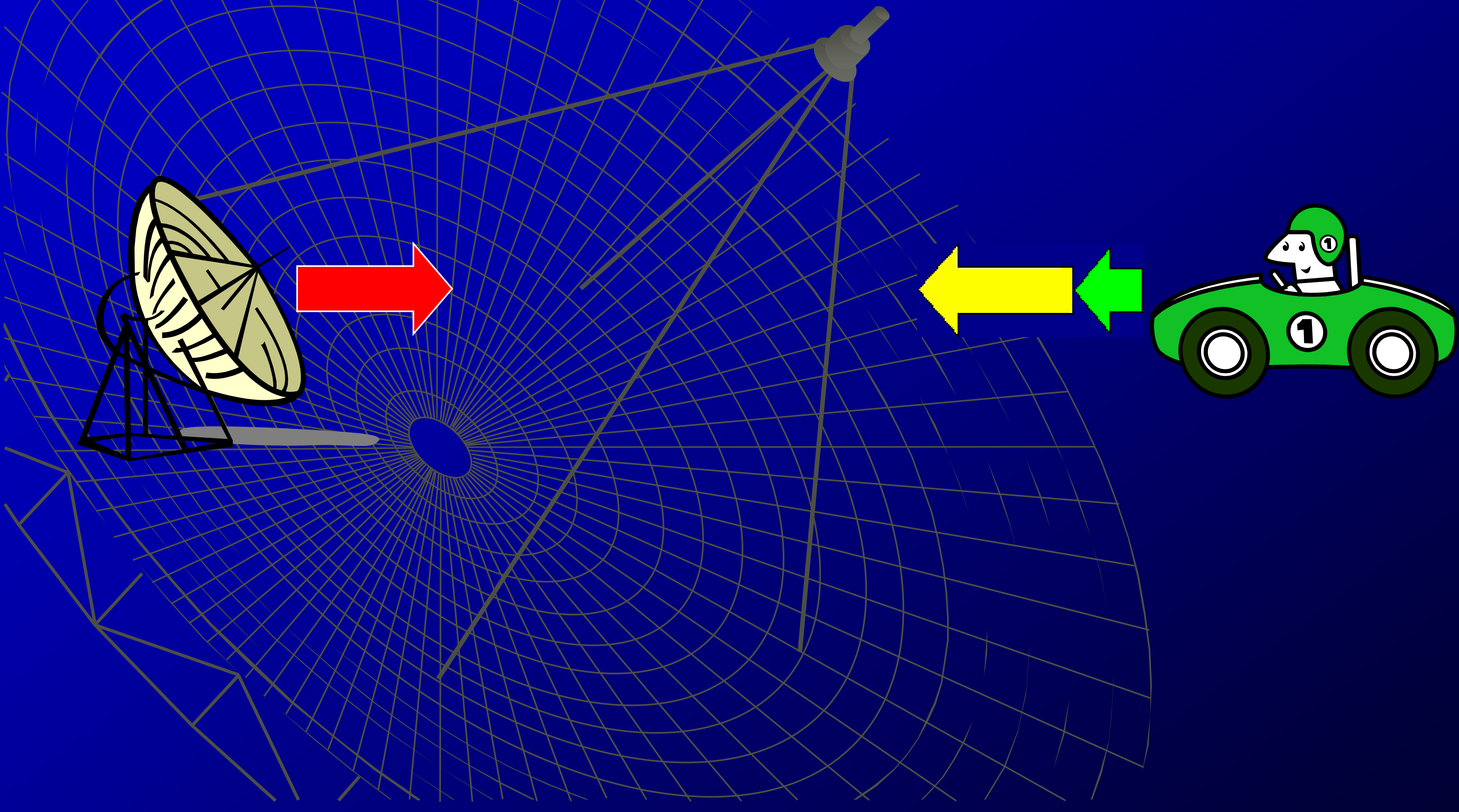
Doppler Radar Simulator Criteria

- Accurately measure speed of moving object
- Operate within police radar band
- Display numerical and graphical results
- Minimum Range of 10 ft

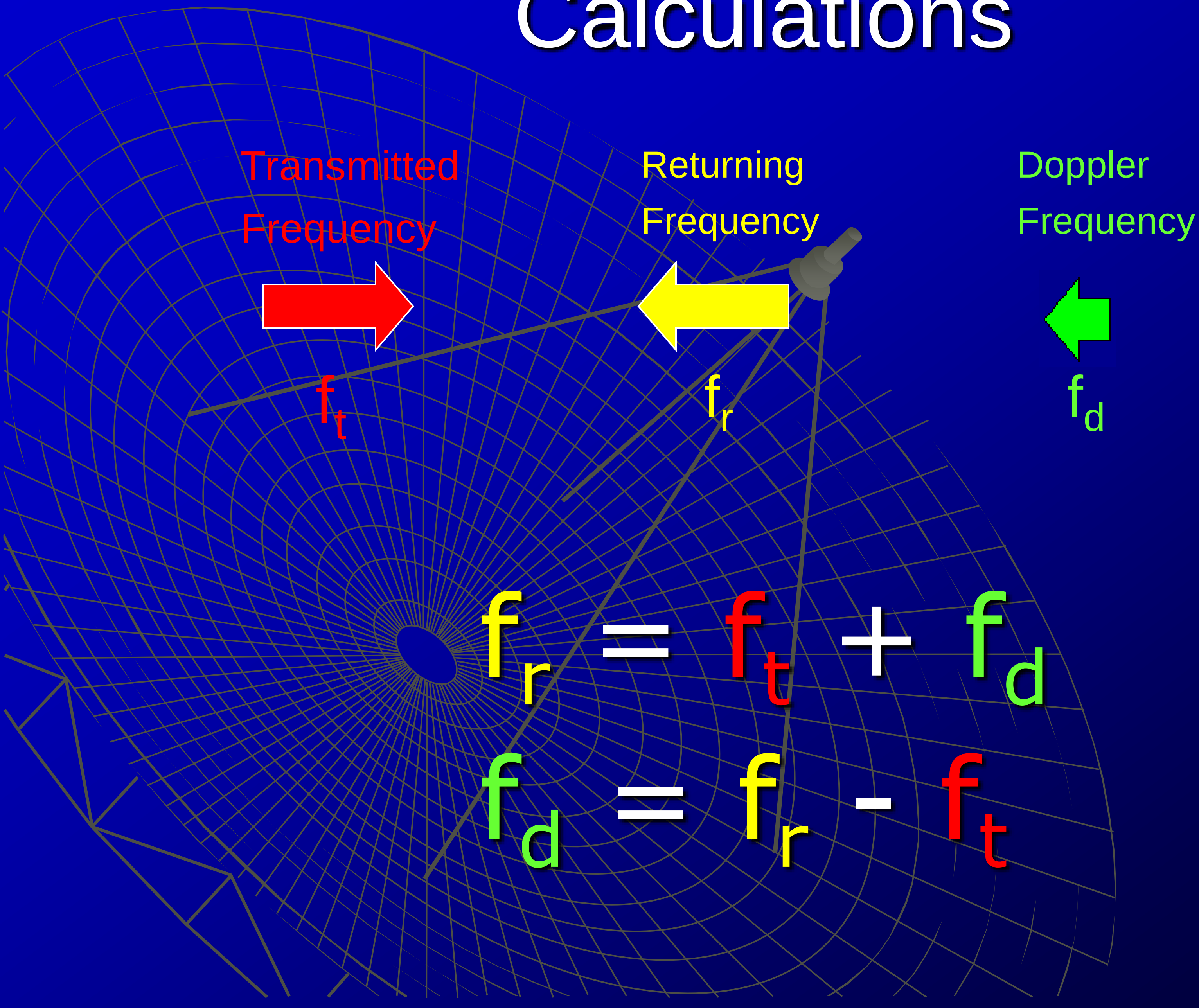
How does Doppler Radar Work?



How does Doppler Radar Work?



Calculations



$$f_r = f_t + f_d$$

$$f_d = f_r - f_t$$

Calculations

$$f_d = \frac{2V_r}{\lambda}$$

where $\lambda = c/f$

$$= \frac{2V_r}{c/f} = \frac{2V_r f}{c}$$

$$= \frac{2V_r f \cos\theta}{c}$$

while factoring target angle

$$= 19.49V \quad \text{Km/hr}$$

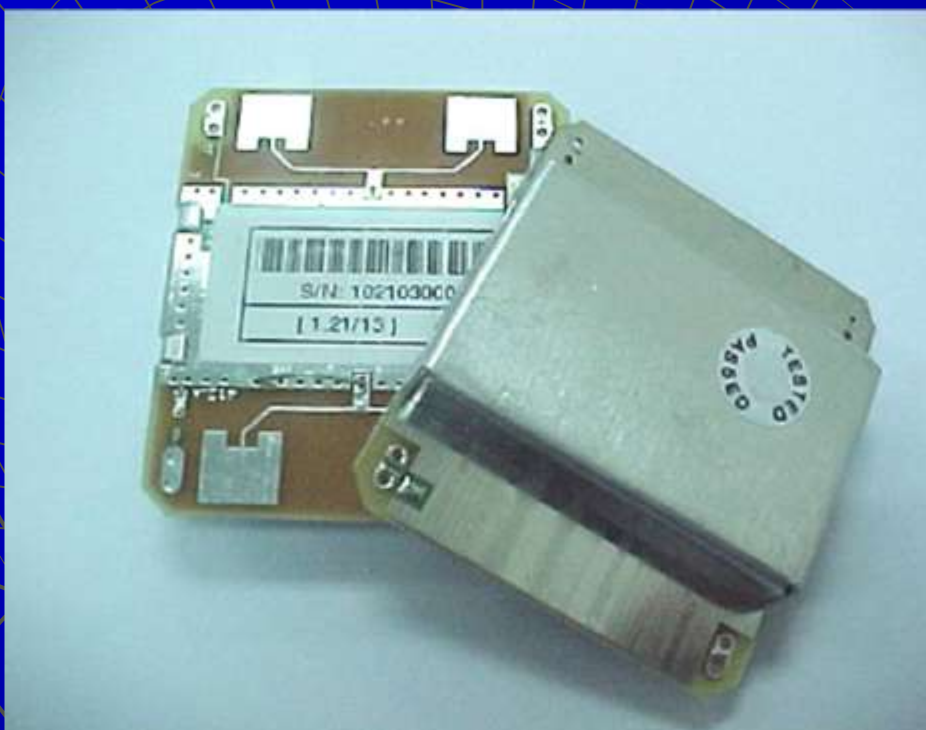
$$= 31.36V \quad \text{mph}$$

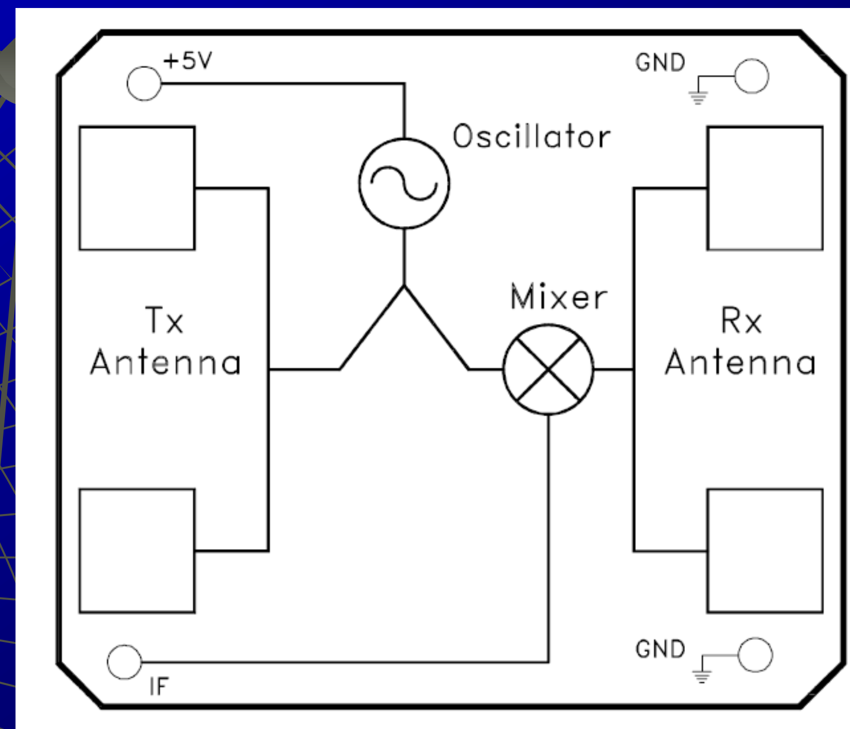
while:

- $c = 3\,E^{8}$ m/s
- $f = 10.525$ GHz
- $\theta = 0$

HB100

Microwave Motion Sensor





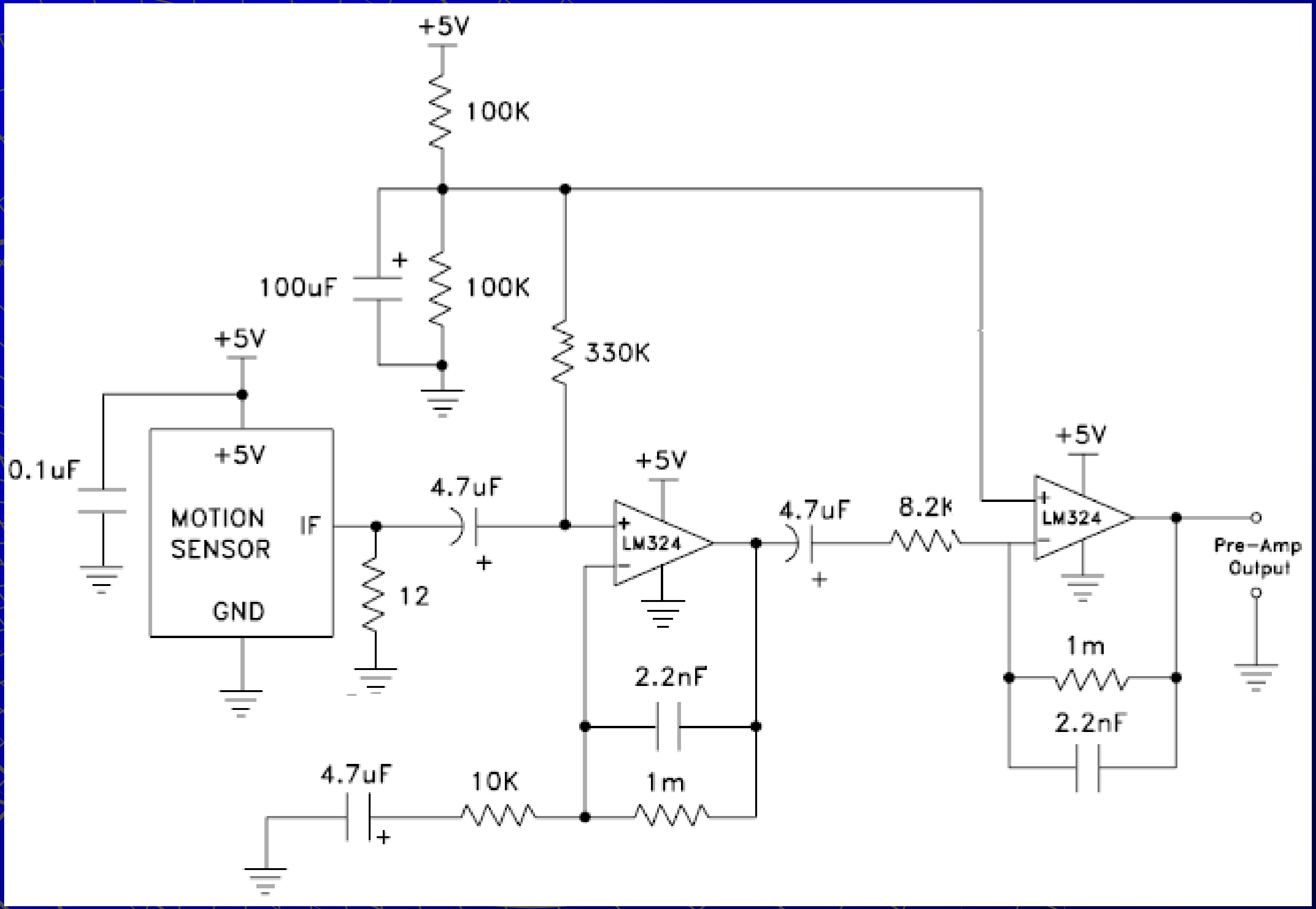
Specs

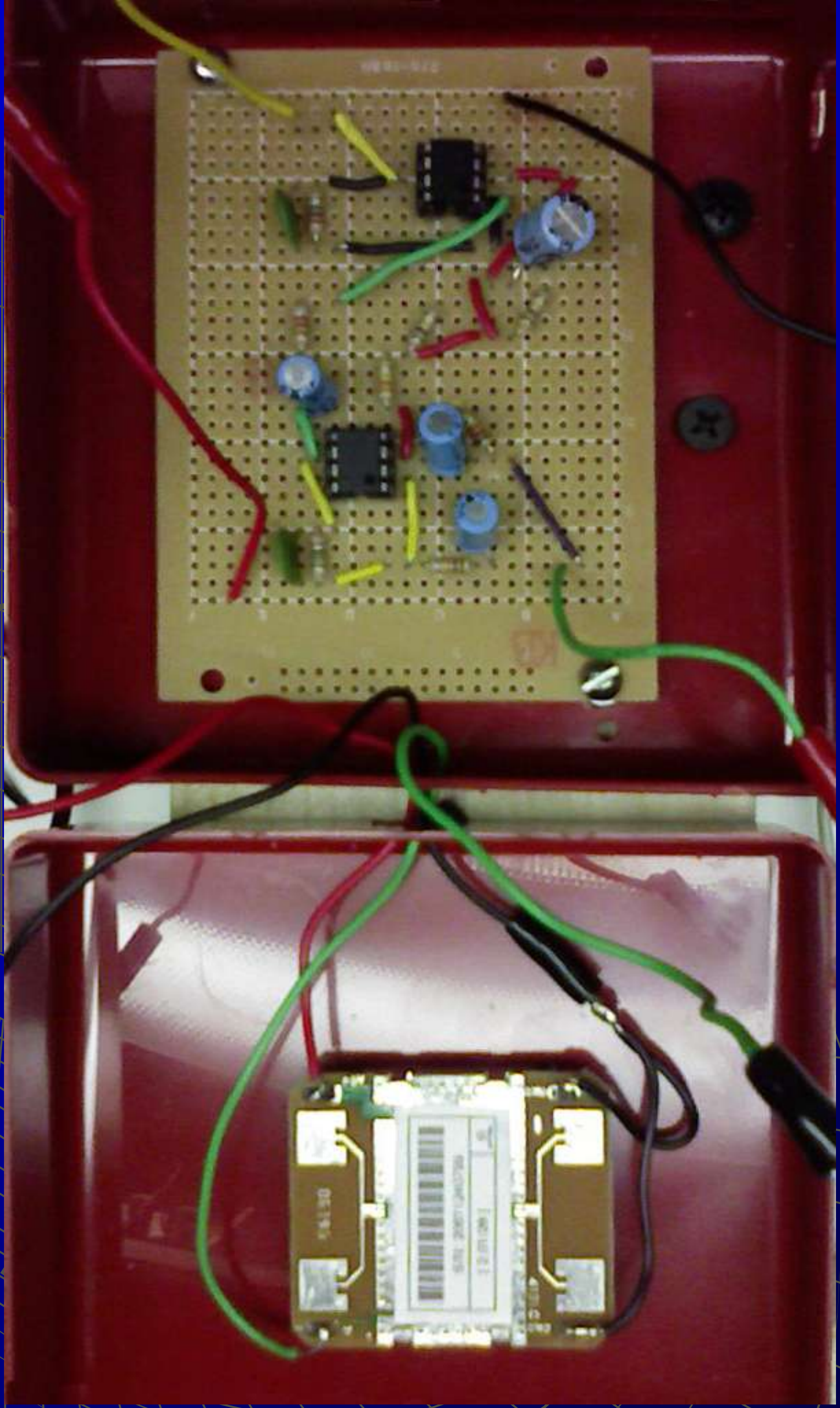
Price	$10	Per unit + shipping
Frequency	10.525	GHz
Radiated Power	15	dBm
Received Signal Strength	200	μVp-p
Weight	9	gm
Operating Temperature	-15° - 55°	°C
Supply Voltage	5	V_{DC}
Current Consumption	30	mA

Amplifier

Low Frequency, High Gain

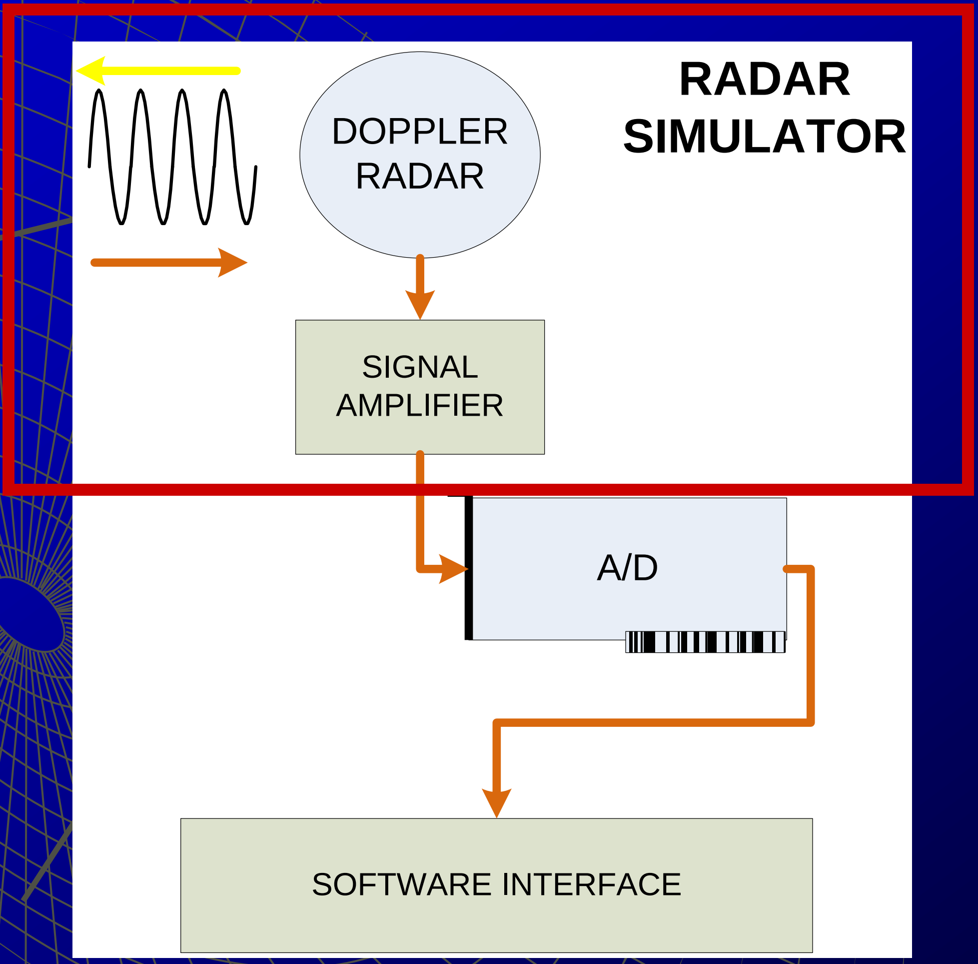
Approximately 40dB gain





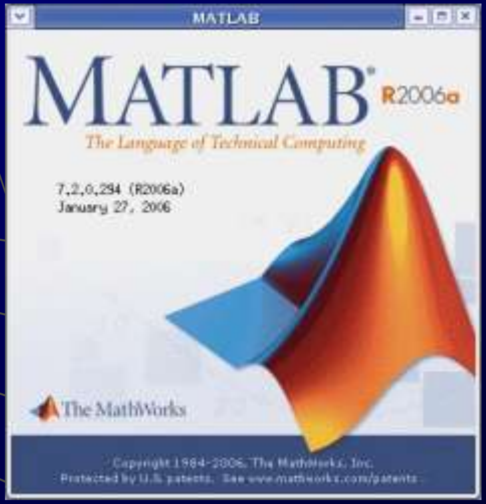
Computer Integration

Integration

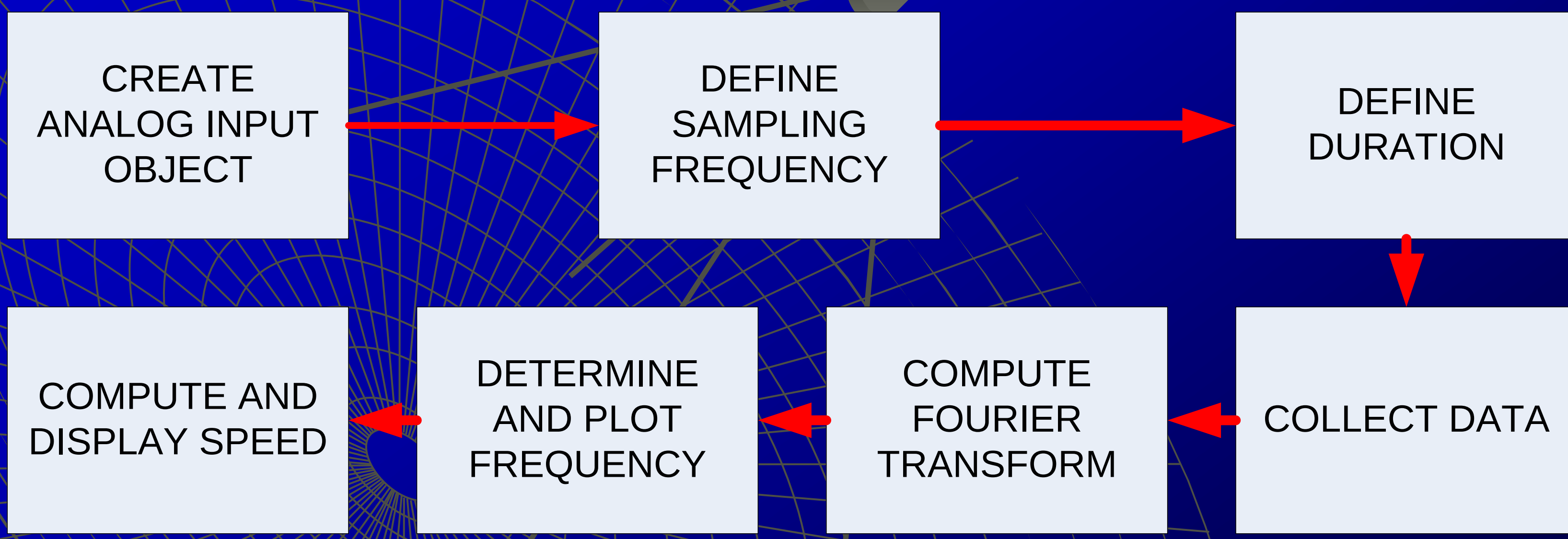


Software Choice

- Software Choice
  - Matlab
    - Many built in functions (Oscilloscope, Data Acquisition, Fourier Transform)
    - Easy to program, great graphical output
    - Most experienced in Matlab
    - Tech Support



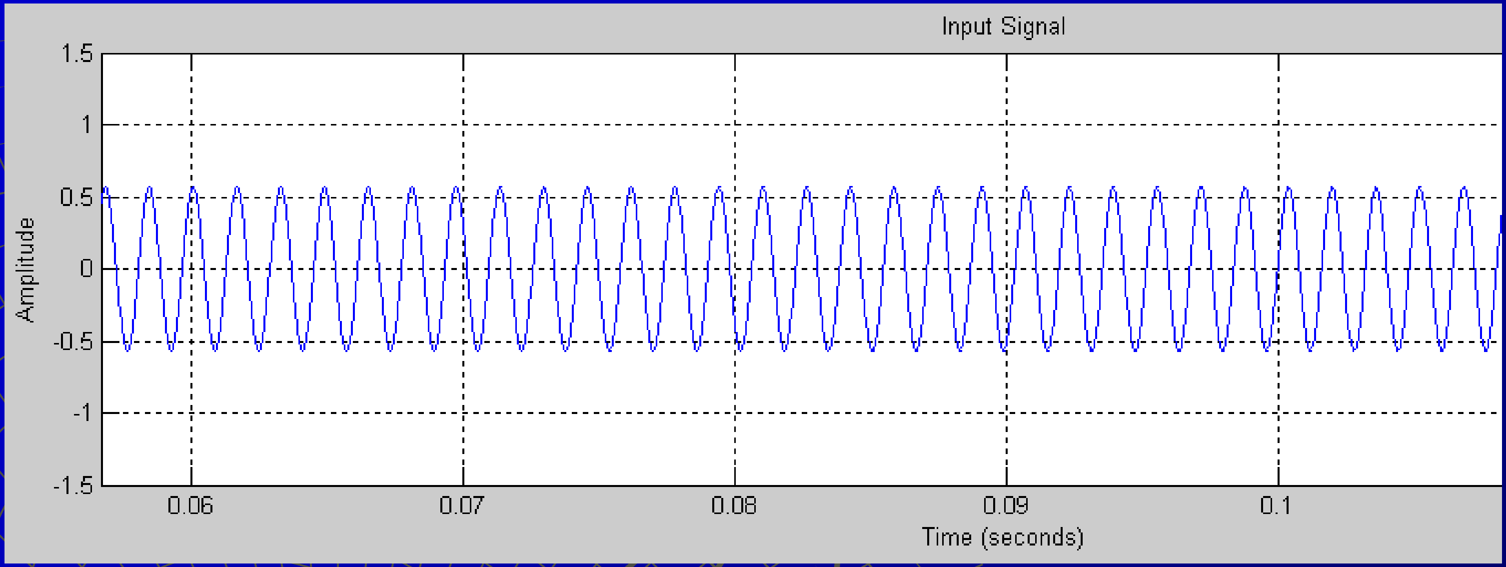
Matlab Algorithm



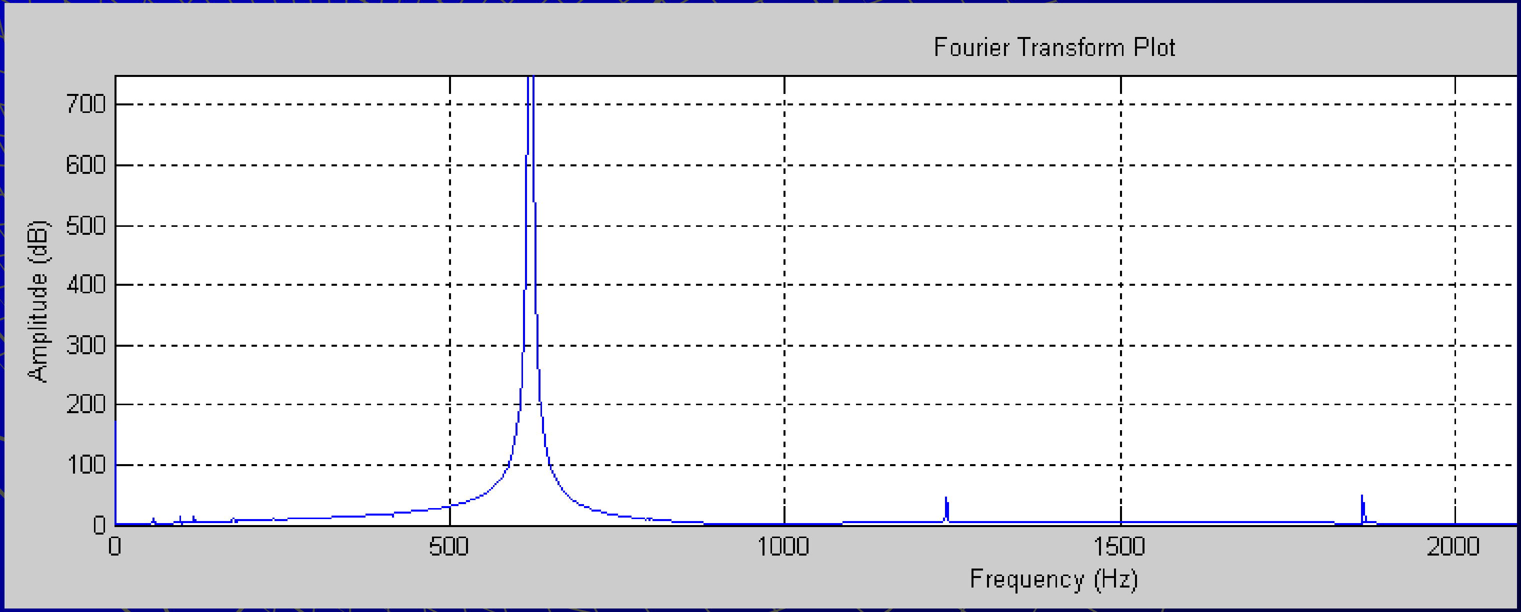
Matlab Code Example

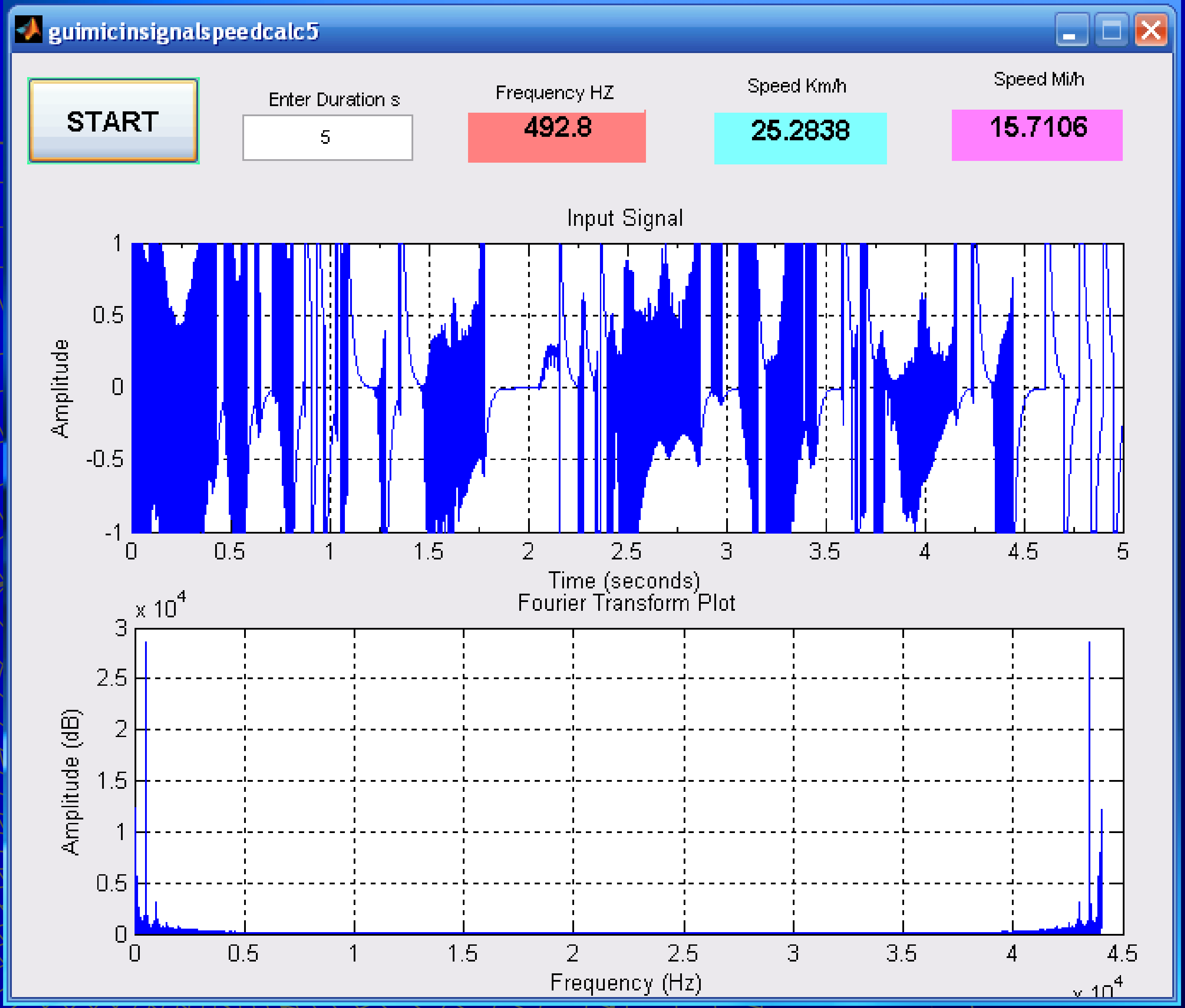
```
% Create an analog input object to communicate with the data acquisition device.
ai = analoginput('winsound');
addchannel(ai, 1);
% Configure the object to acquire 'duration' seconds of data at 'Fs'Hz (max 44000Hz).
fs = 44000;  % sampling frequency
duration = 1;   % how long to read the signal
set(ai, 'SampleRate', fs);  %
set(ai, 'SamplesPerTrigger', duration*fs);
% Start the acquisition and retrieve the data.
start(ai);
signal = getdata(ai);

%Finding Fourier Transforms of current signals
SFT=fft(signal,size(signal,1));     %Message Signal

% Converting data into Frequency (Hz) x-axis
freq = (0:size(signal,1)-1)*fs/size(signal,1);                  % calculate Hertz values
% Convert data into Magnitude (dB) y-axis
mag = 20*log10(abs(SFT));                 % convert magnitude into dB
mag = mag(1:floor(size(abs(SFT)/2)));  %this line will convert 2 dim matrix to a single

% Convert data into Time (s) x-axis
time=(0:1:size(signal,1)-1)./fs;

% Calculating Frequency
[ymax,maxindex]= max(mag);
maxfreq = freq(maxindex);
fprintf('Frequency is %f Hz', maxfreq); % display frequency

% Calculating Velocity
c = 3e8;
Ft = 10.525e9;  %HZ
lambda=c/Ft;
speedms = (maxfreq*lambda/2); % Value in meter per second
speedkmh = (speedms*3600)*(1/1000);
speedmph=speedms*0.000621371192*3600;
fprintf('The speed of the target is: %f km/h  rounded %f mi/h', speedkmh, speedmph);
```

Graph of Input Signal (Time Domain)



Graph of Fourier Signal (Frequency Domain)





- Generate an executable file
- Can be run from any windows OS

Radar Spoofer

Different Methods of Spoofing

Active Noise Jamming

- Continuously transmits noise
- Detectable implementation
- Illegal broadcasting

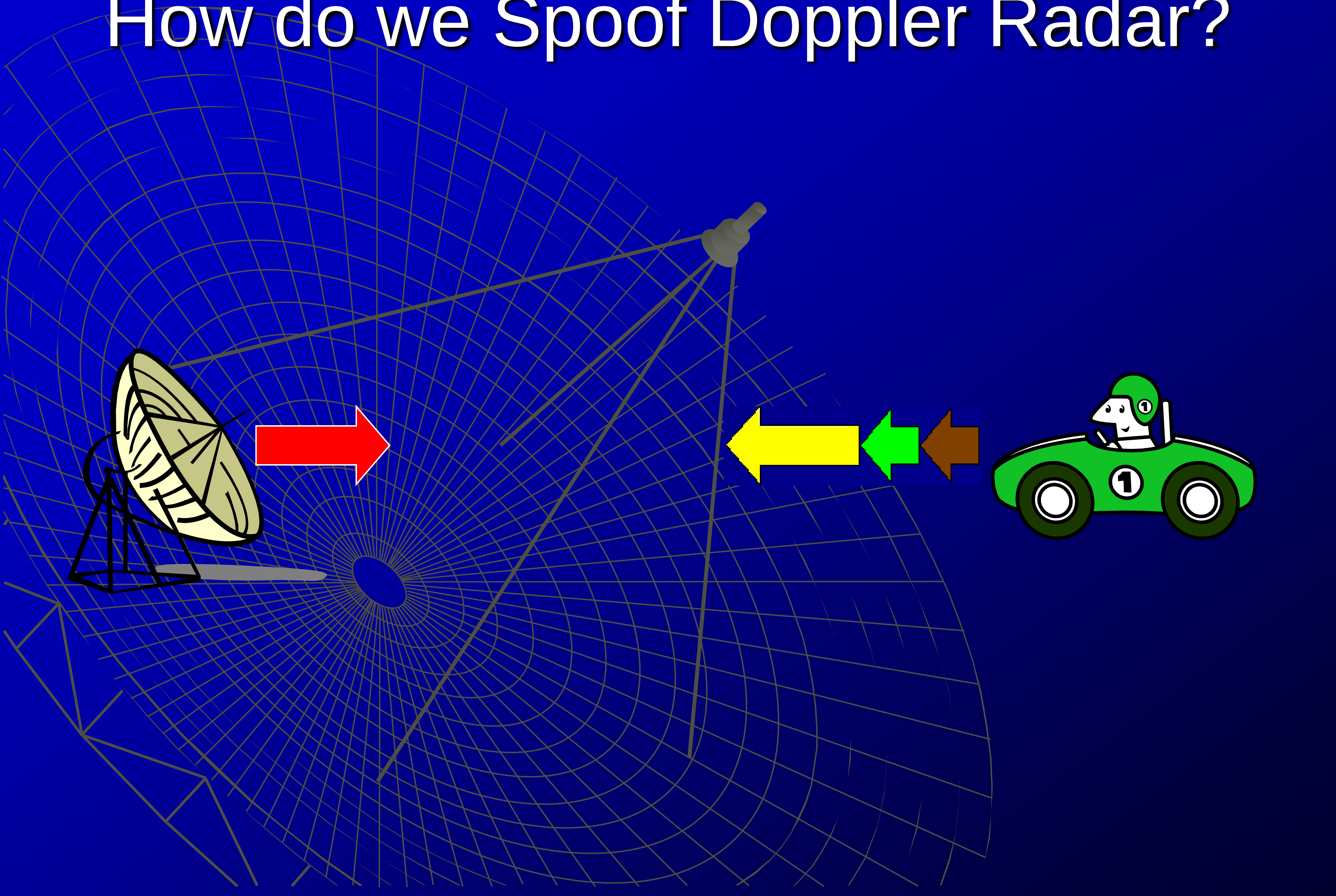
Active Deception Jamming

- Triggered transmission of specific frequency
- Illegal broadcasting

Passive Deception Jamming (Spoofing)

- Modulates incoming radar signal and reradiates modified signal
- Legal

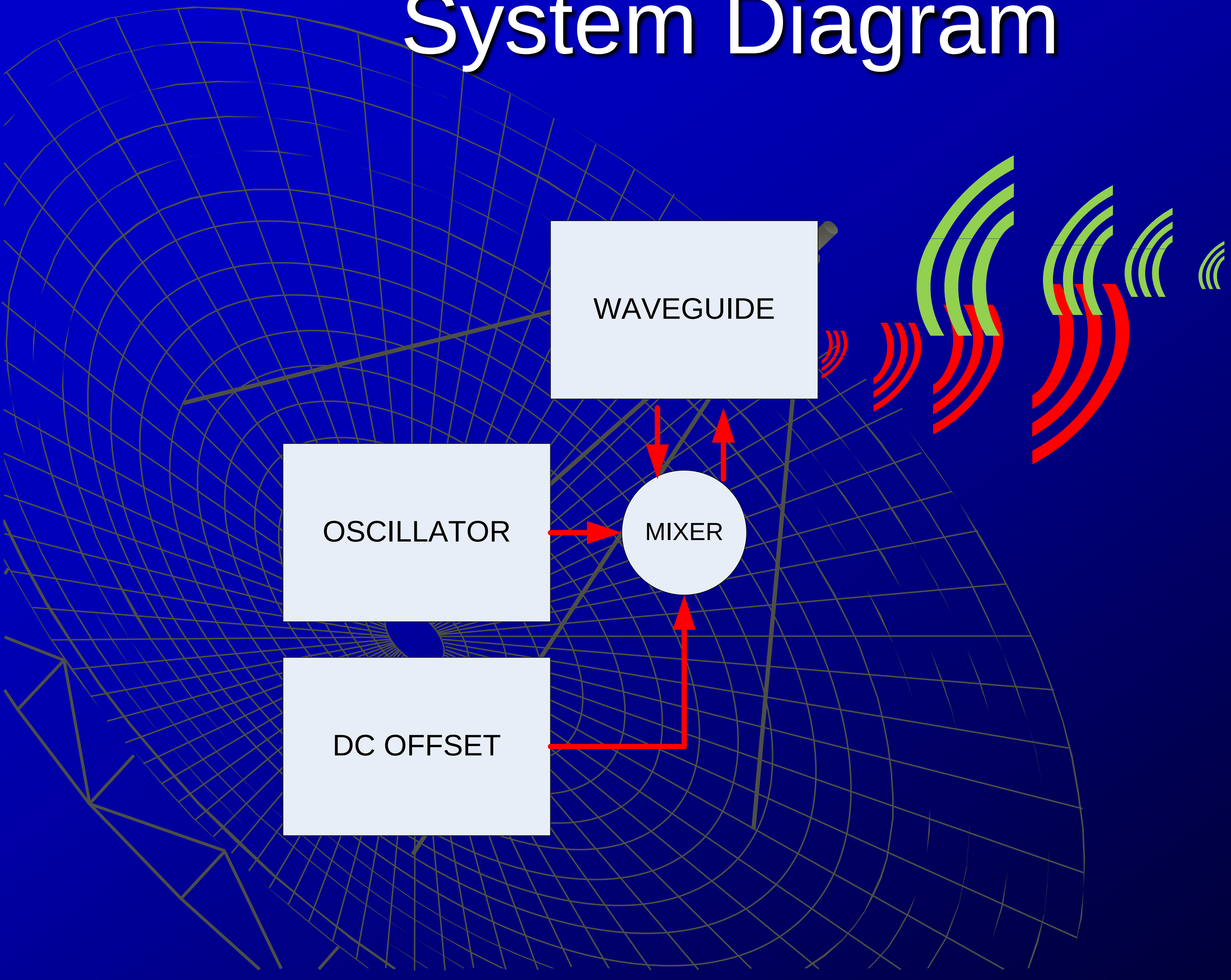
How do we Spoof Doppler Radar?



Radar Spoofer Criteria

- Spoof doppler radar signal
- Operate on police radar band
- Operate autonomously once activated
- Battery powered
- Maximum dimensions 6” X 4”
- Capable of in class testing

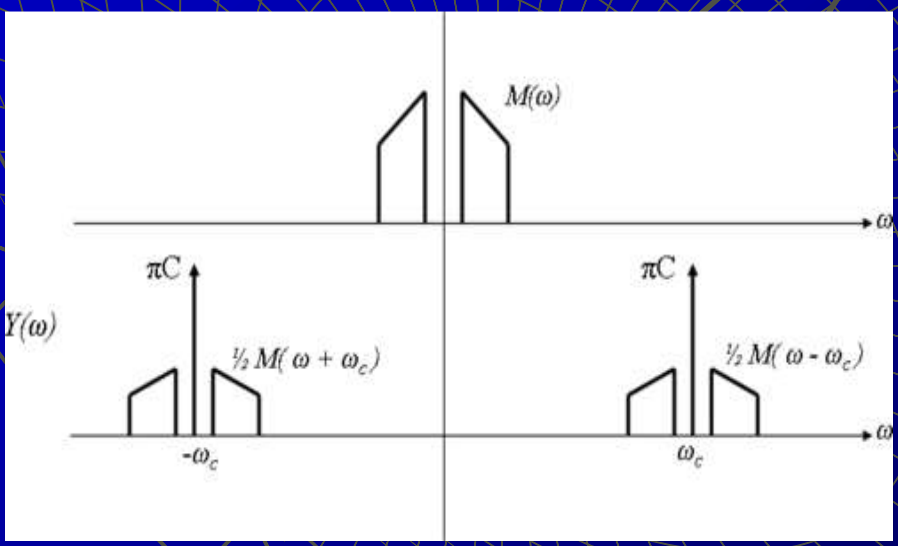
System Diagram

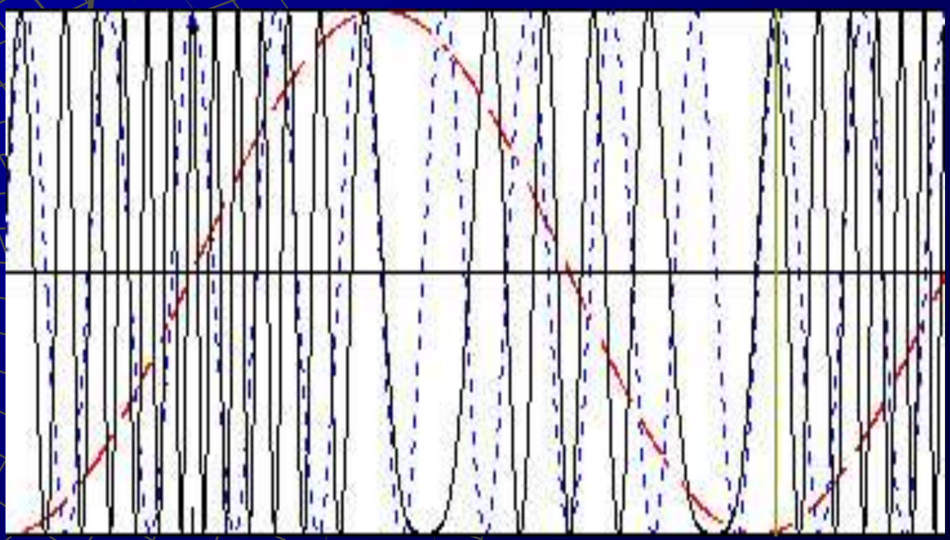


Options for Signal Alteration

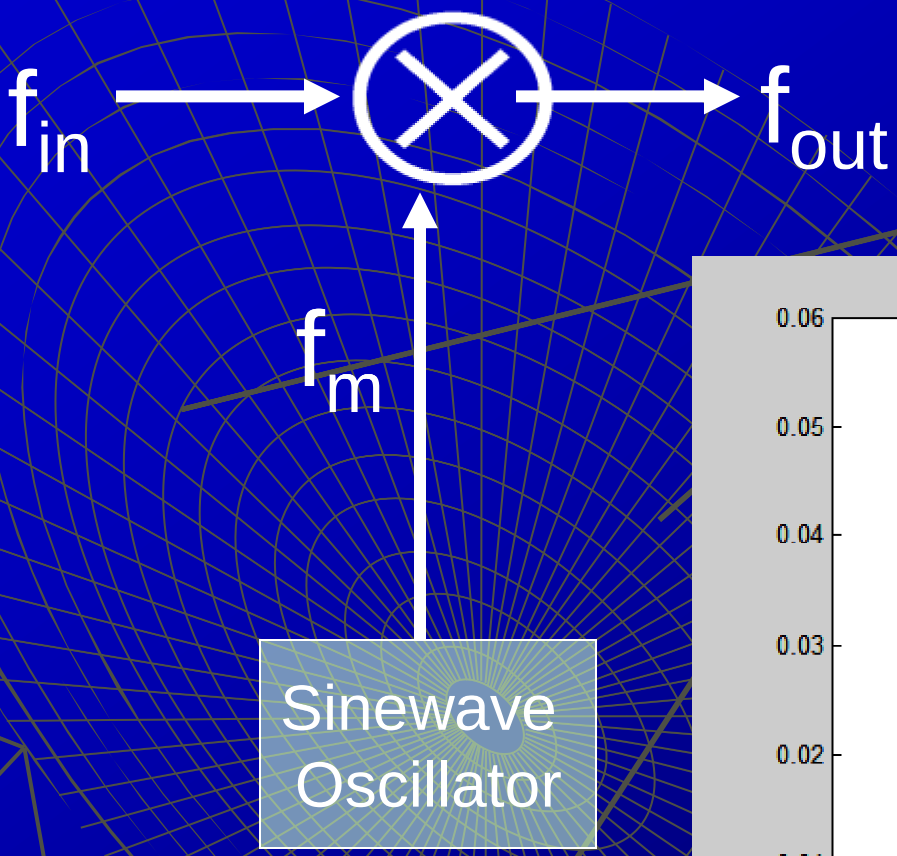
- **AM**
- Radio transmission
- Variation of amplitude while frequency is constant
- Ease of implementation

- **FM**
- Radio transmission
- Variation of frequency while amplitude is constant
- More sophisticated

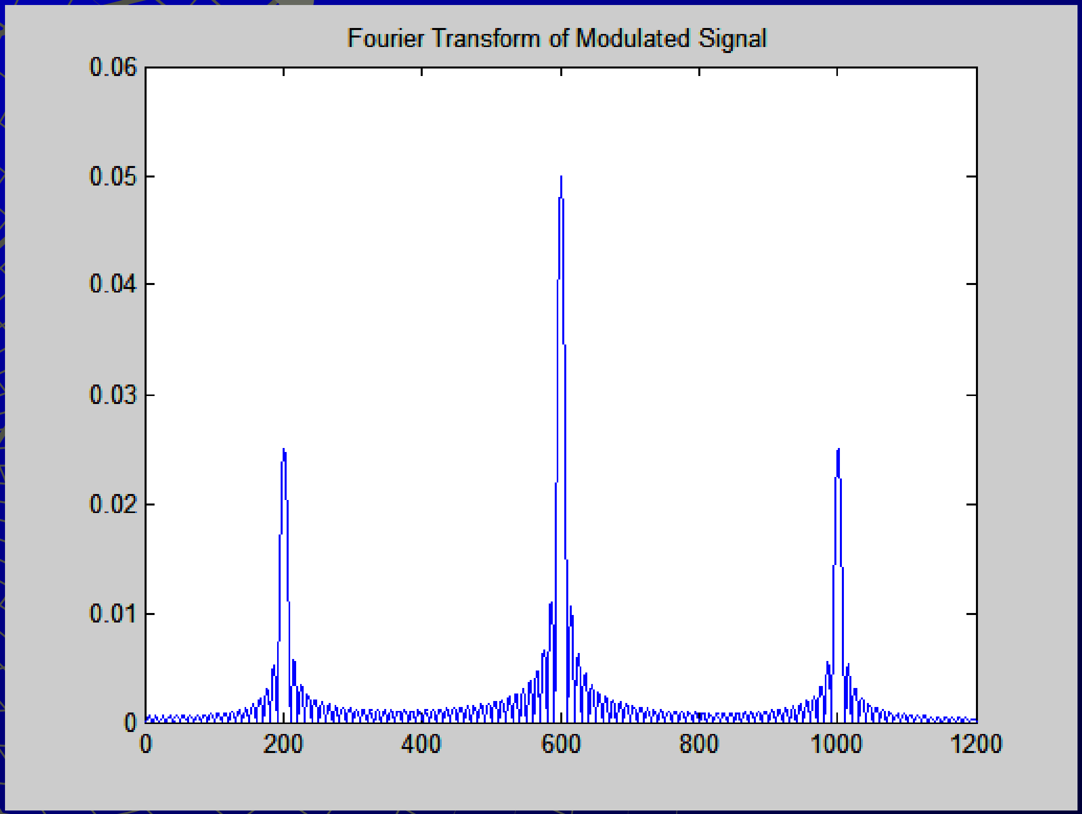




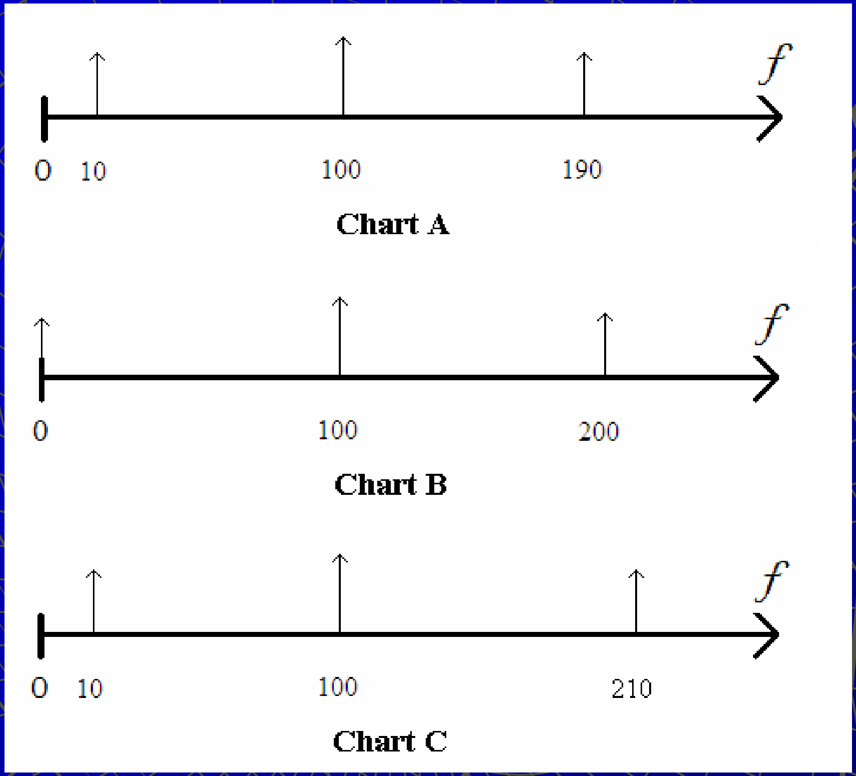
AM: Basic Operation



$f_{out} = f_{in} +/- f_m$

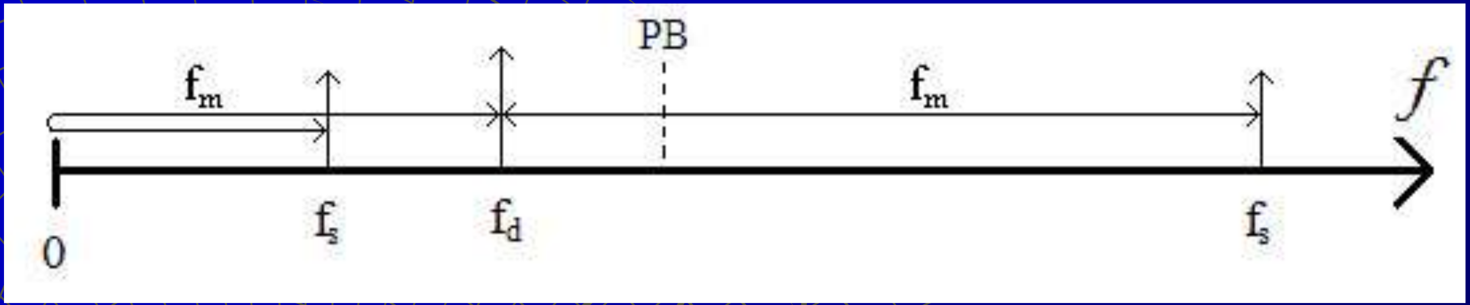


AM: Frequency Behavior



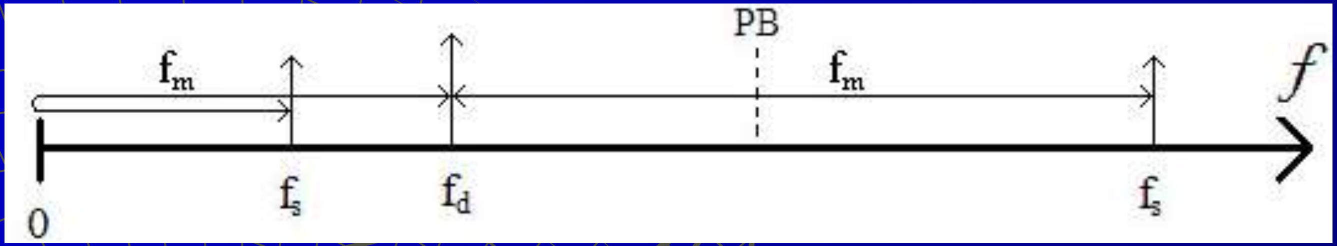
- Frequency can not be negative
- Once frequency becomes 0, frequency increases in positive direction

Radar Passband Filter



- Realistically, all radars have a passband filter with the cutoff point set at a certain frequency
- Purpose is to filter out noise and unwanted frequency components

Calculation



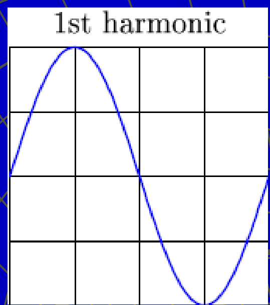
$f_d=2*V/\lambda$ --> $V=f_d*\lambda/2$						
Real speed		Spoof speed		Real	Spoof	
Vr(mph)	Vr(m/s)	Vr(mph)	Vr(m/s)	fd(Hz)	fd(Hz)	fm(Hz)
100.00	44.69	70.00	31.29	3136.06	2195.24	5331.30
100.00	44.69	50.00	22.35	3136.06	1568.03	4704.09
10.00	4.47	7.00	3.13	313.61	219.52	533.13
10.00	4.47	5.00	2.23	313.61	156.80	470.41
10.00	4.47	7.00	3.13	313.61	219.52	94.08
10.00	4.47	5.00	2.23	313.61	156.80	156.80

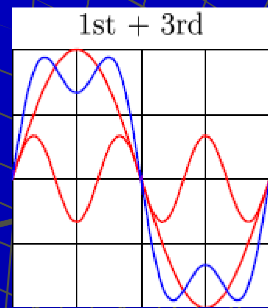
Oscillator

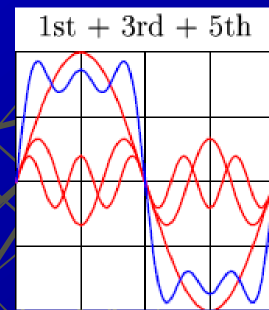
LM555CN

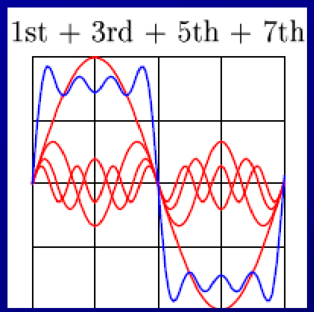
- 5-16V supply voltage
- Easy to obtain a square wave with 50% duty cycle
- Adjustable frequency by varying the value of 1 resistor
- Output sources up to 200mA
- Inexpensive

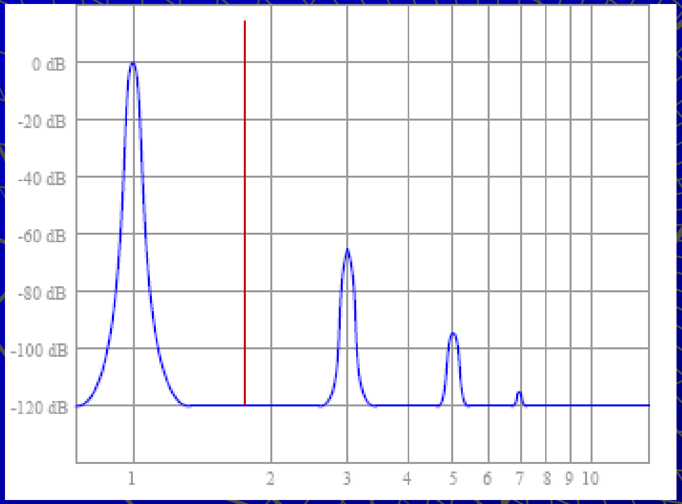
Properties of Square Wave



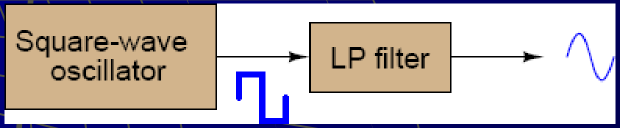








$$v_{square} = \frac{4}{\pi} V_m \left(\sin \omega t + \frac{1}{3} \sin 3\omega t + \frac{1}{5} \sin 5\omega t + \frac{1}{7} \sin 7\omega t + \cdots + \frac{1}{n} \sin n\omega t \right)$$



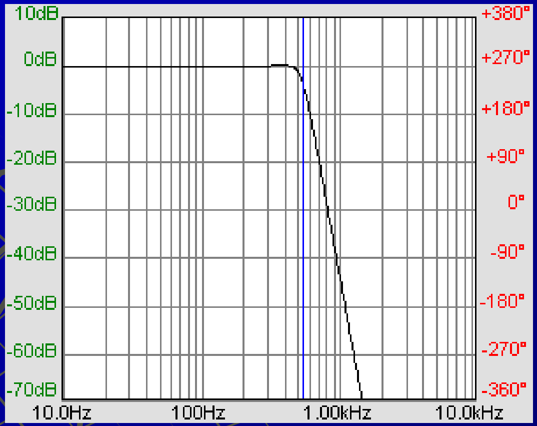
- Pass the square wave to a LPF to get sinewave

Lowpass Filter

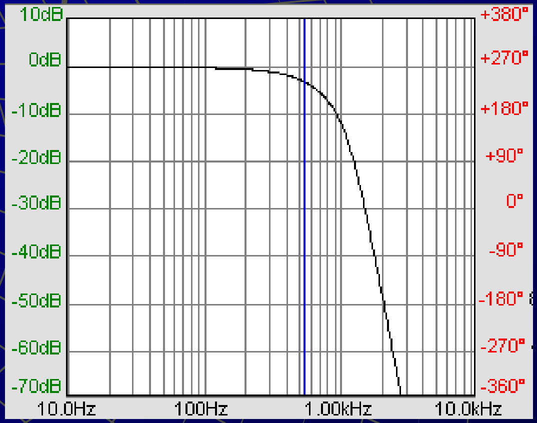
MAX7480

- 5V supply voltage
- 8th order Butterworth LPF
- Low noise distortion
- Clock tunable f_{cutoff}
- Low output offset
- Low power consumption

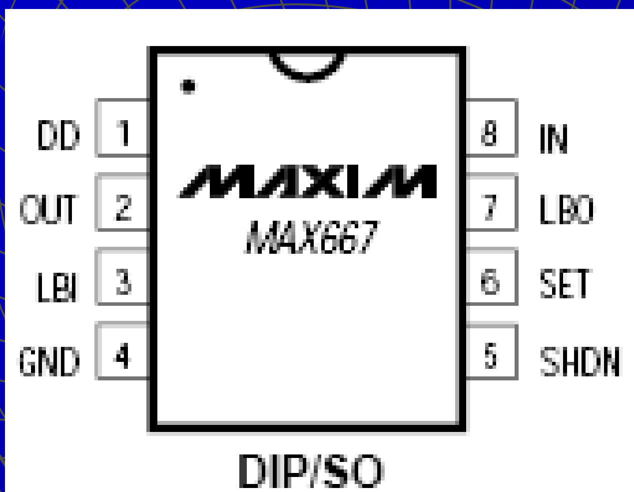
Butterworth



Bessel

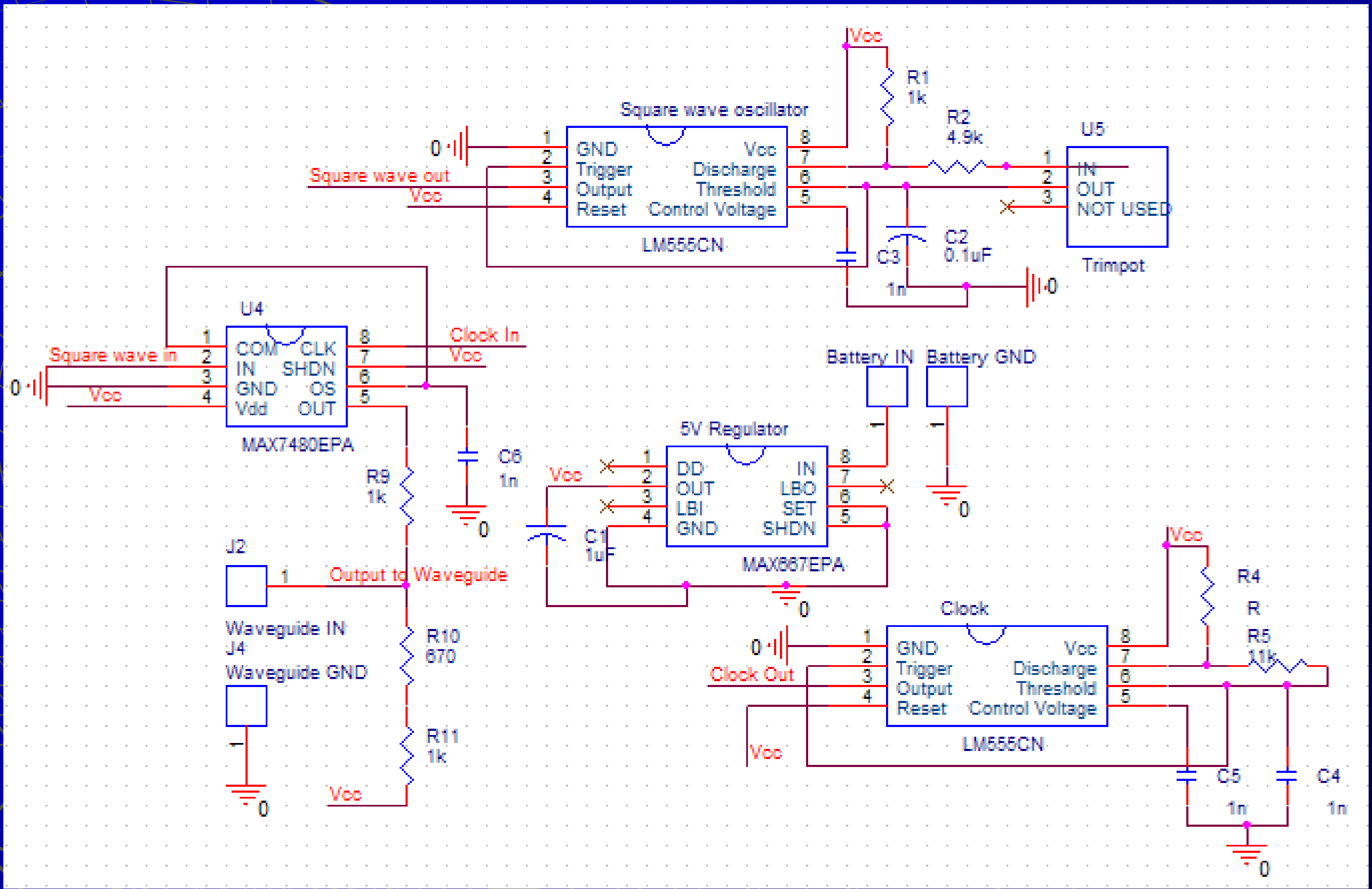


Voltage Regulator

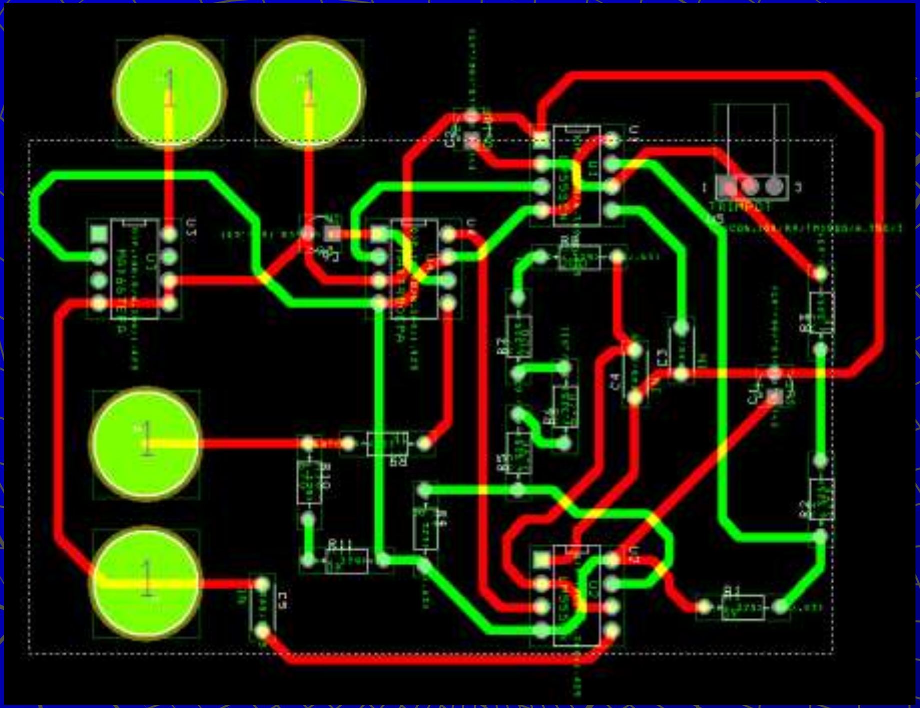


- 3.5 → 16.5V input
- Max adjustable voltage 15V with preset at 5V
- Max output current 250 mA
- Low battery detector

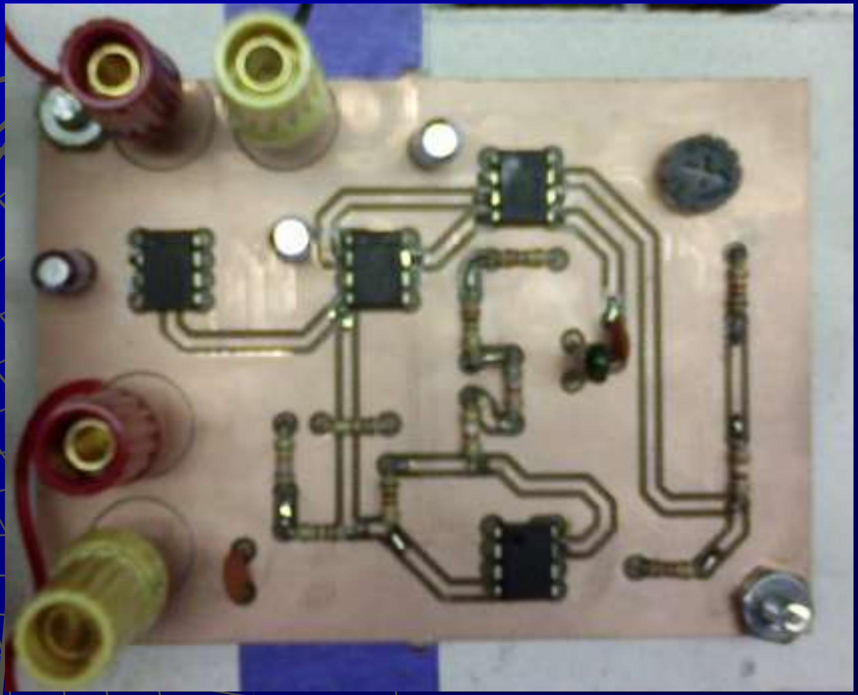
Circuit Design



PCB of Spoofing Circuit



PCB Design in Orcad



Fabricated PCB

Waveguide

Characteristics:

- Hollowed inside for wave propagation
- RF diode mounted inside
- Can operate as signal detector or mixer
- Allows for larger radar cross-section

Waveguide

Detector Mount Requirements

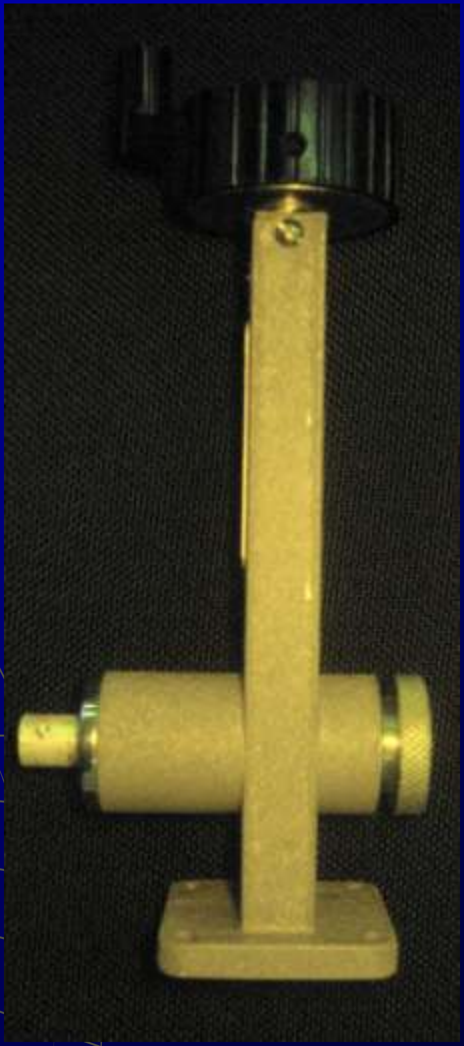
- Operate within police band
- Preferably tunable
- Weight restrictions
- Size restrictions

Waveguide

Part: X485B

Mfr: HP/Agilent

- X-band(8.2-12.4 GHz)
- Tunable
- BNC
- Diode crystal: 1N23
- Cost: $95 + S/H
- Weighs < 1 lb
- Appx. 5.5×1.5 inches



Horn Antenna

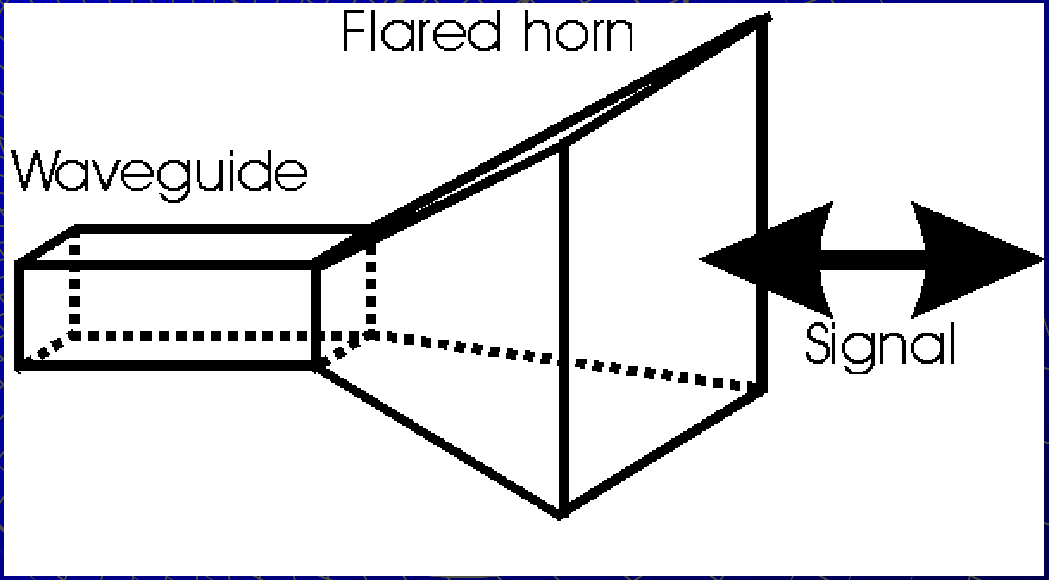
- Characteristics:
- Purpose is to be mounted at opening of waveguide
- Flares out from base
- Increases the gain for applications requiring higher signal strength
- Expensive if purchased on market

Horn Antenna

Solution:

- Elected to build our own
- Foam mold with aluminum foil along interior

- Appx 5” long attachment to end of waveguide
- Opening appx 3” x 2”
- Negligible weight



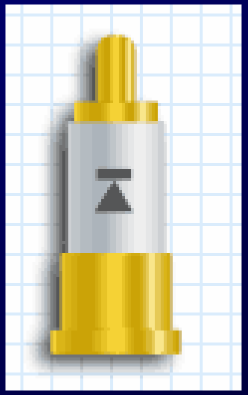
Mixer Diode

Requirements:

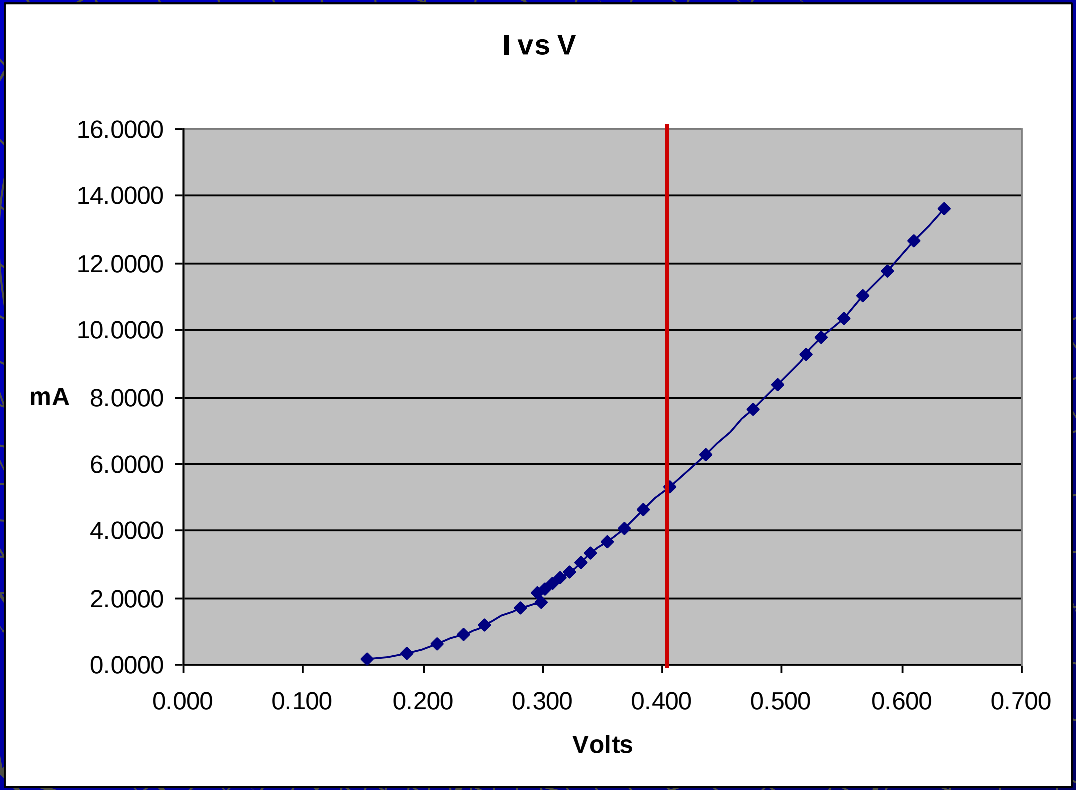
- Needs to be square law, relationship of $V=I^2$
- 1N23 crystal
- VSWR should be close to 1

Solution:

- Samples from Micrometrics
- 1N23 crystal with removable base
- VSWR = 1.3



IV Characteristics



- First section square law, then linear relationship
- Must propagate within square law section to maintain mixing characteristics

Testing

Test Procedure 2

Proving the Spoofing Device works

- Trial run # 1 : Spoofer OFF
  - Determine actual speed of a target
- Trial run # 2 : Spoofer ON
  - Same test variables, observe spoofed speed

Budget

Part	**Cost**
Waveguide	$ 101.50
Microwave Diodes	Donated
Microwave Motion Sensor (8)	$ 130.00
Amplifier	$ 7.00
555 Timers	Donated
Low-Pass Filter	Donated
Voltage Regulator	Donated
Circuit Materials	Donated
Test Vehicle Materials	$ 17.50
Test Track Materials	$ 8.00
Other Components	$ 50.00
Total	**$ 314.00**

Test Procedure 1

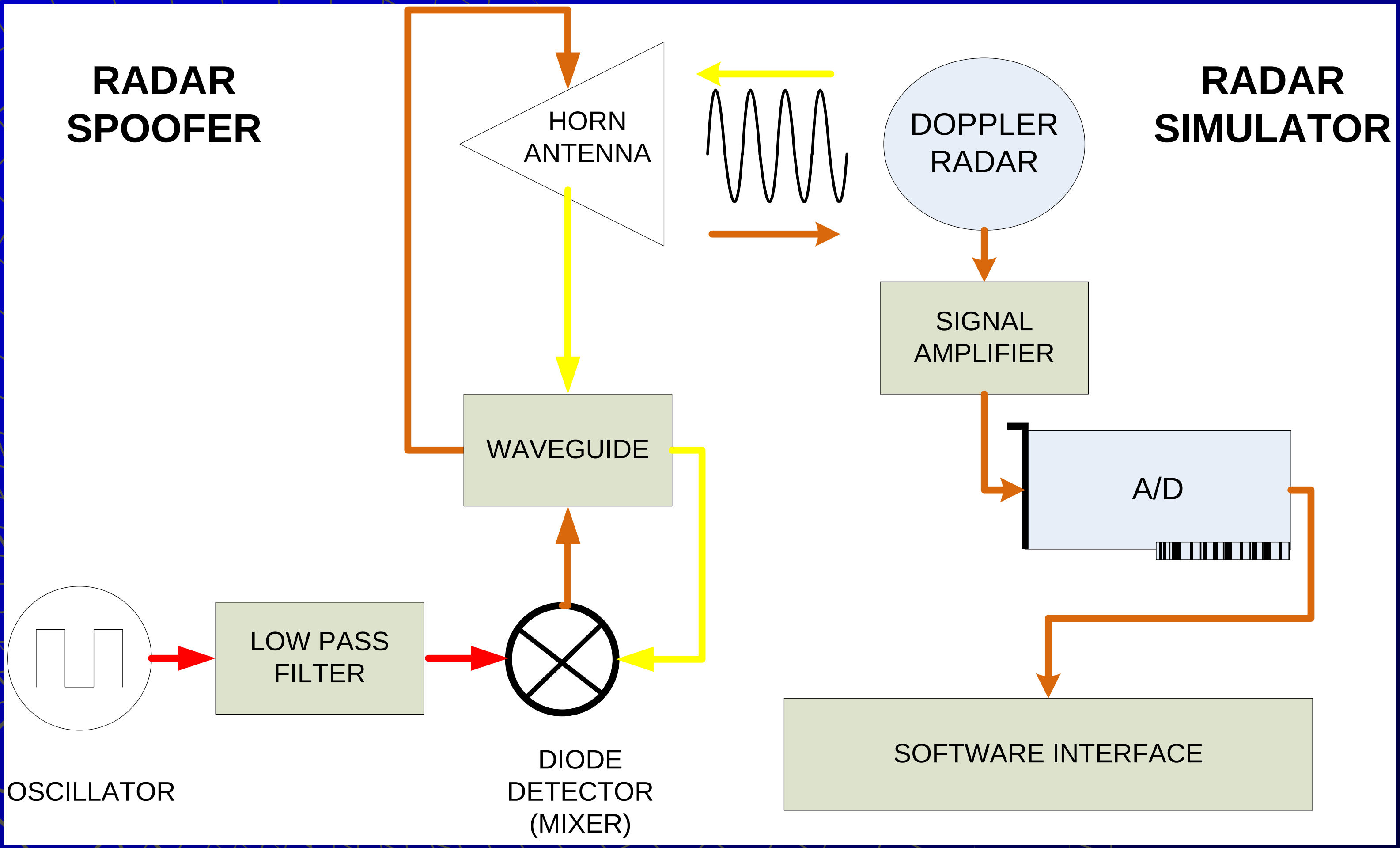
Proving the Radar Works

Compare speed measured by Radar
to speed determined through timed trial

Work Distribution

Justin	Johnny	Sam	Vlad
Radar Spoofer		Test Car & Track	
Waveguide & Detector	Oscillator & Current Amplification	Radar Transmitter & Amplification	Computer Integration
Testing			

Questions?


RADAR SPOOFER
HORN ANTENNA
DOPPLER RADAR
RADAR SIMULATOR
SIGNAL AMPLIFIER
WAVEGUIDE
A/D
LOW PASS FILTER
OSCILLATOR
DIODE DETECTOR (MIXER)
SOFTWARE INTERFACE