Radio Design 201 Microwave Circuits and Antennas
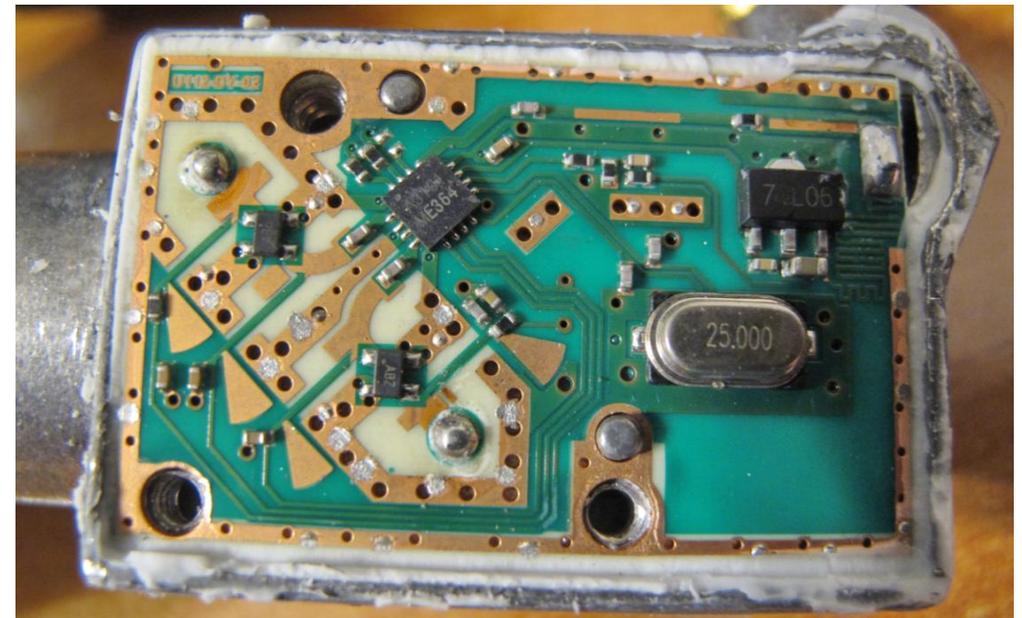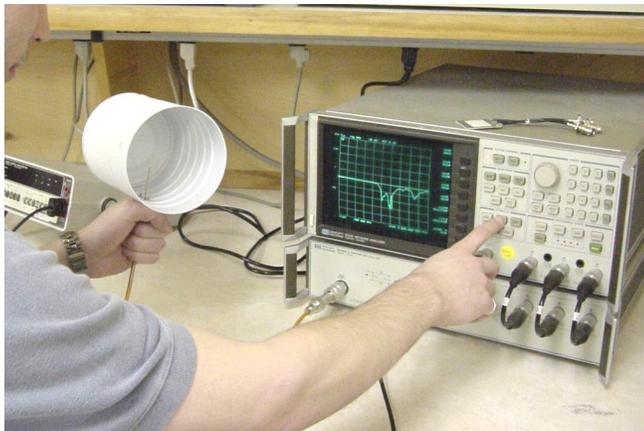## Episode 2 - Project and Product Examples

Slides downloaded from: https://ecefiles.org/

Companion videos at: https://www.youtube.com/playlist?list=PL9Ox3wpnB0kpOb7NdpHAK-jDpsZm3Xedx

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In this second episode of Radio Design 201 we show some of the projects done in a university course on Microwave Circuits and Antennas, as well as some commercial products. Projects and products include satellite ground station receivers, Doppler and CWFM radars for automobiles, and commercial LNBs. We also overview the use of microstrip line structures to build bandpass filters, biasing structures, and other microwave circuits. Our introduction will continue in episodes 3, and 4 before we step into the lectures making up the core material in the series.

Microwave Circuits and Antennas
Project & Product Examples
Radio Design 201 #2
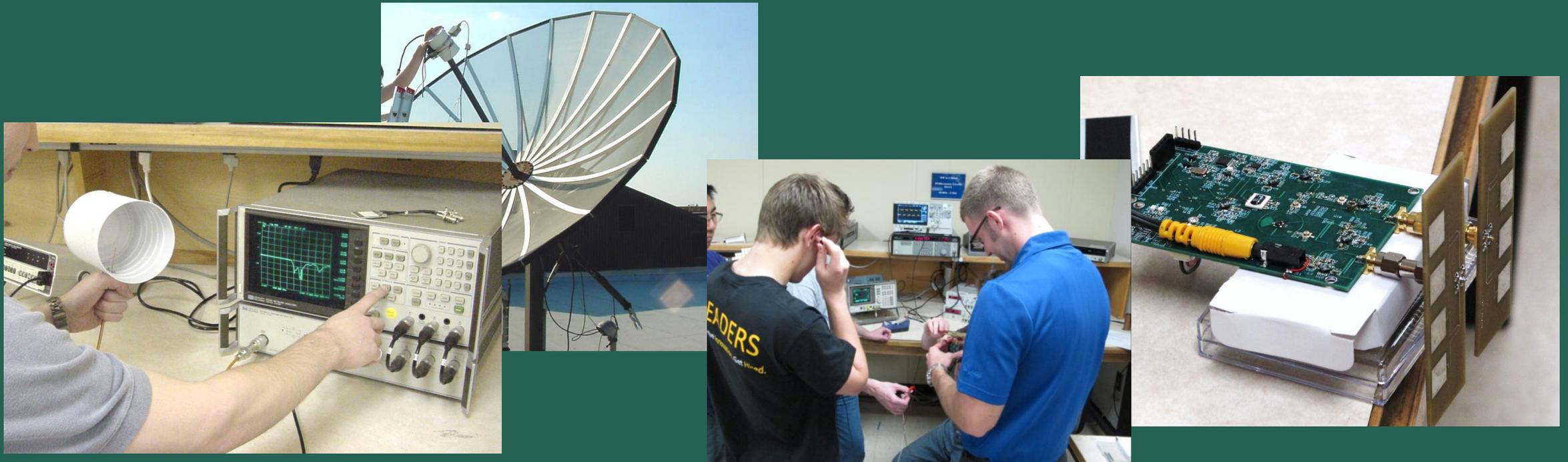
Recall Alternative Definition of "Microwave" (from Episode 1)

- Radio frequencies where the size of the electronic components and /or interconnects used is larger than about 1/10th to 1/20th of a wavelength

Speed of Light

$$\lambda = \frac{(v_r)c}{f}$$

Wavelength

Frequency

Frequency (f)	Free-Space Wavelength (λ)	$\lambda/20$	Microwave ?
100 MHz	3 meters	15 cm (6 inches)	Nope. Just VHF
2.4 GHz	12.5 cm	6 mm (240 mils)	Yes? Depends …
24 GHz	1.25 cm	600 um (24 mils)	Yes, for PCB design. Maybe for IC design. Yes, for (most) packaging.

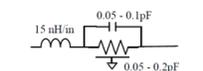# From Radio Design 101 Appx C

Class Handout on Parasitics
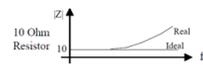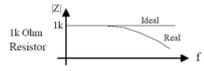
8

Component Parasitics at RF

Resistors

or

Ideal Model

Model at RF

15 nH/in   0.05 - 0.1pF
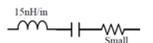
0.05 - 0.2pF

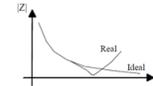Impedance vs Frequency

10 Ohm Resistor
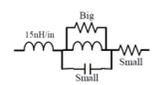
1k Ohm Resistor

Capacitors

or

Ideal model

Model at RF   15nH/in

Impedance vs. Frequency

Inductors

Ideal Model

Model at RF   15nH/in   Big   Small
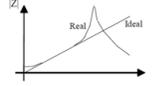
Small

Impedance vs Frequency

PC Board Trace

Top Side Trace

Back Side Ground Plane
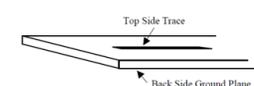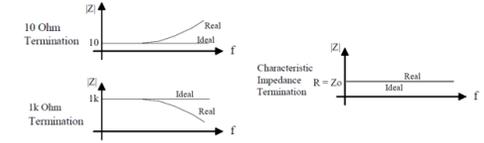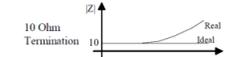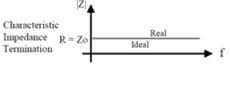
Ideal Model

Model at RF
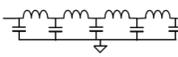
Impedance vs. Frequency *(When terminated at one end with a resistor to ground.)*

10 Ohm Termination

1k Ohm Termination

Characteristic Impedance Termination   R = Zo

PCB traces, wires, etc are *transmission lines* at "high frequency".
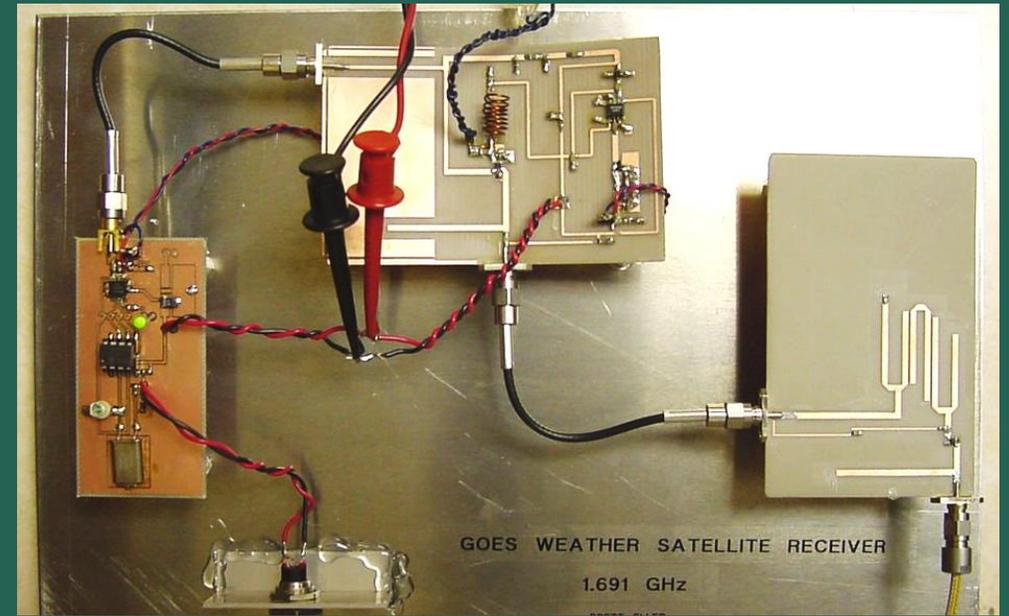
Important if length is > 1/10 wavelength
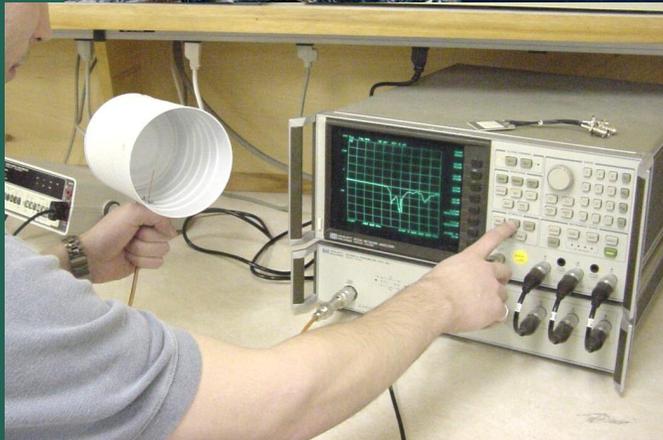
$$\lambda = \frac{c}{f} v_r$$

$$v_r \sim 0.5$$

$$\Rightarrow \frac{\lambda}{10} \approx 1.5\ cm\ at\ 1\ GHz$$

L, C, and characteristic impedance varies with trace width and board interlayer thickness

Early Projects at 1.7 GHz:
GOES Weather Satellite Receiver

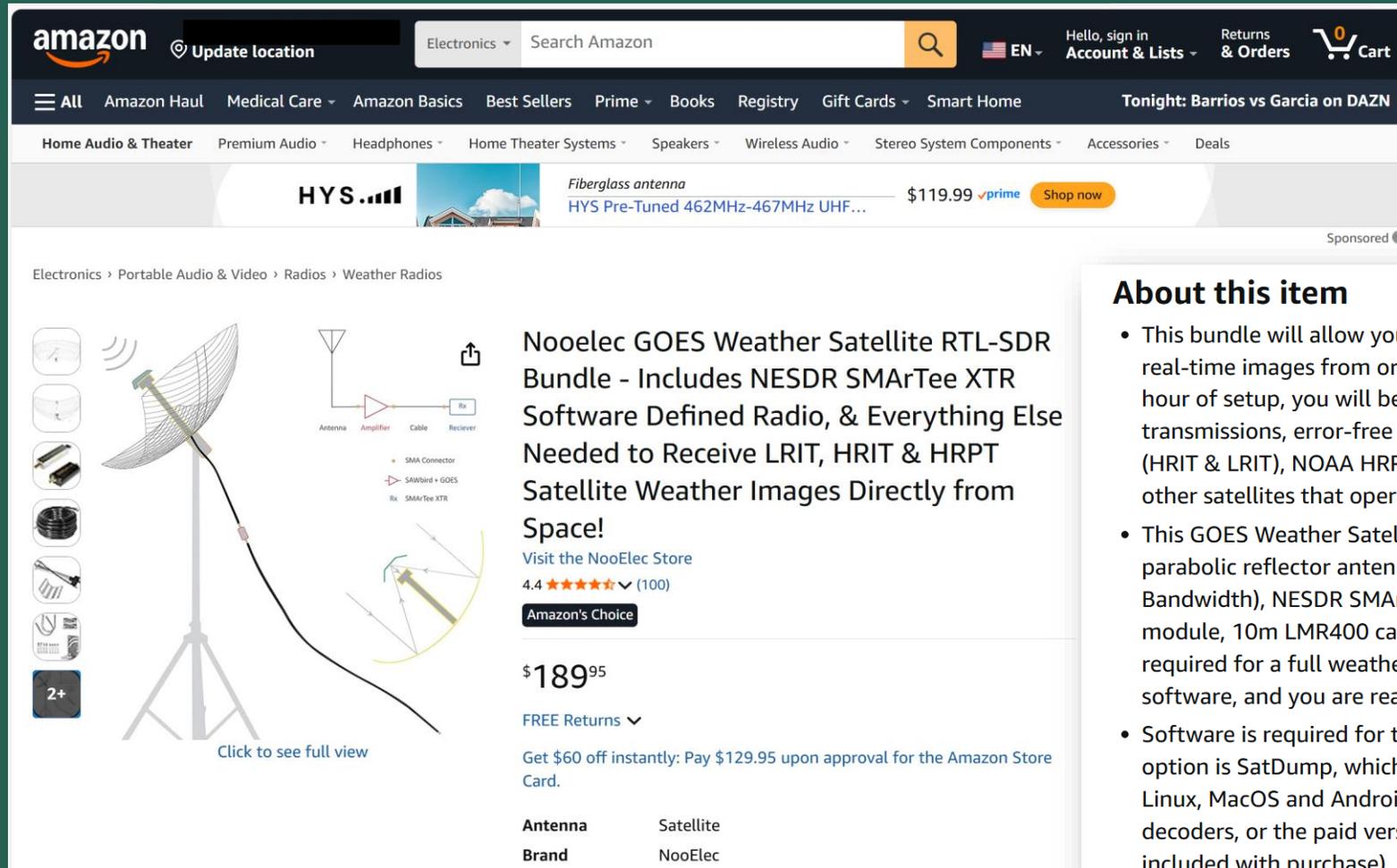https://www.noaa.gov/media/image_download/
85c2a492-fc0b-4988-91e9-700f3d7da4b4

GOES WEATHER SATELLITE RECEIVER
1.691 GHz

Credit: KSU ECE Students

MegawattKS - YouTube

https://ecefiles.org

2026 Commercial GOES Satellite Receiver

Projects at 5.2 GHz: Doppler Radar

Credit: KSU ECE Students
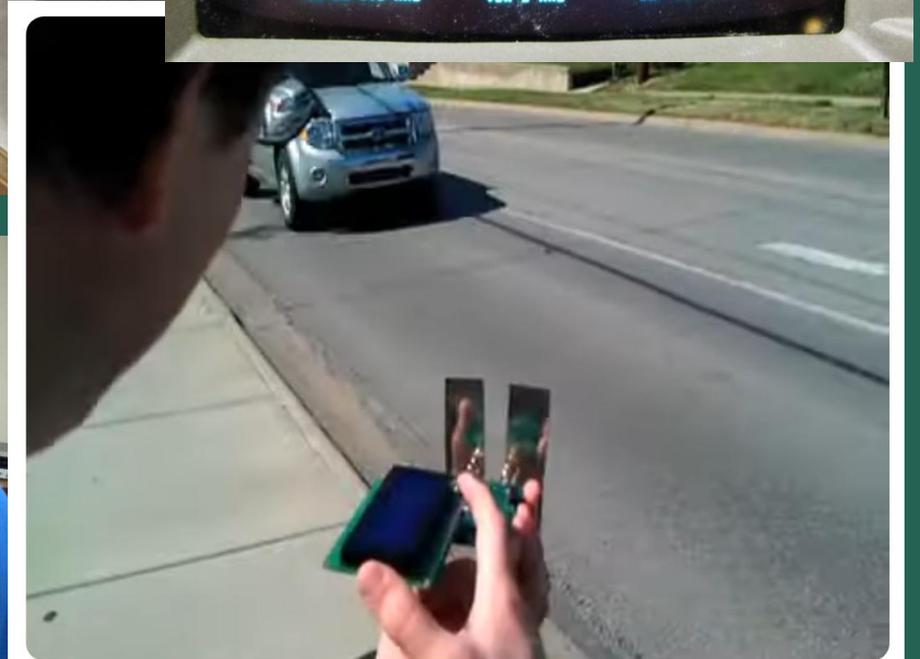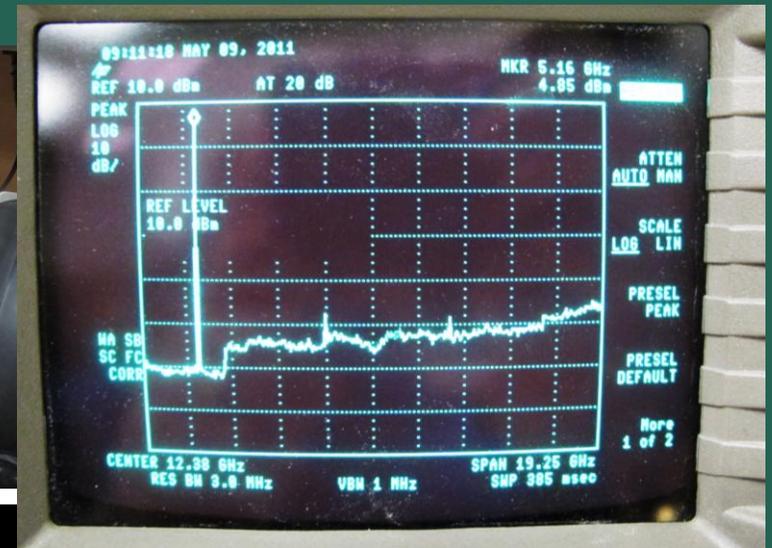
Design of a Microwave Radar

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Project Assignment and Teams/Companies

Background and Team Formation

During the remainder of the semester, we will be designing, building, and testing a microwave system - a doppler radar operating in C-Band at 5.25 GHz. To keep the workload manageable, we will operate as two companies with six "employees" each.

Within each company, three 2-person teams will be responsible for the three different "subsystems" of the project (see block diagram on next page). Hence, I will be collecting information on team/company formation in about one week and you must decide which of the three subsystems of the radar you and your teammate will do:

1. C/X-Band Source Module (with optional frequency synthesizer) - 2 persons
2. Transmit/Receive (TR) Module with cylindrical horn antennas - 2 persons
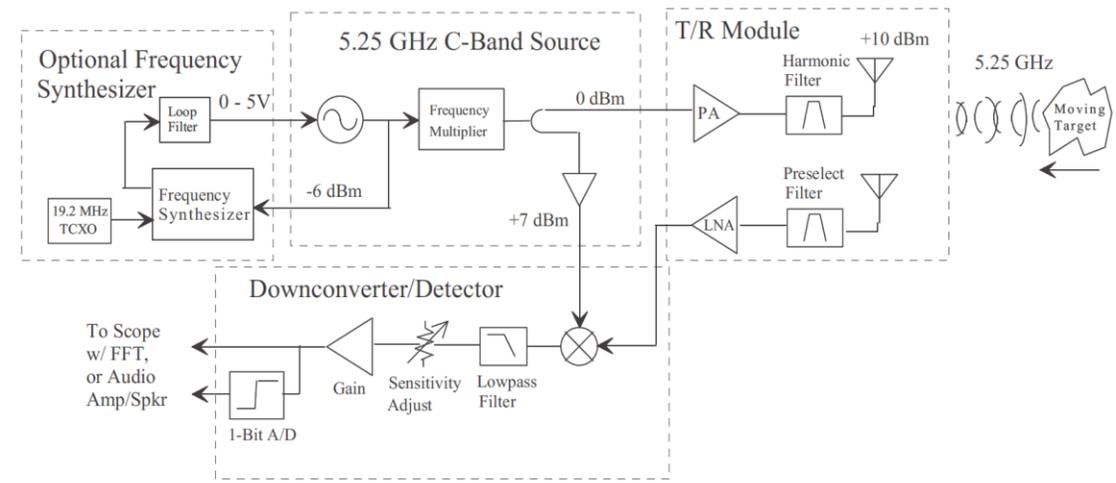3. Downconverter/Signal-Processing Module - 2 persons

In addition to forming your companies/teams, you should look at the datasheets for the parts you have available and begin work on the designs so that your team/company agree on the gain and power levels at various points in the radar. Some suggested levels are given in the block diagram on the next page, but you must create a more detailed diagram showing individual IC components, together with the power levels at the inputs and outputs of each. Be sure to look a the gain compression values and work with your teammates as you make these decisions.

Your company should have all 3 subsystems fabbed and functional by the end of the month to allow for a possible "re-spin" of your PC board to correct problems you may find. To increase the chances of achieving a successful demo earlier in the month even if one or more components within your radar are not working, the three subsystems are specified in the diagram on the next page so as to allow mixing of boards between companies if. Therefore, do not deviate from the specified subsystem interfaces without your instructor's consent. Also, be sure to do good "design-for-test" by providing u.fl connectors at key points in the system (as discussed in class). This will allow us to jumper between boards, as well as to test the individual subsystems indpendently (THIS IS CRITCAL).
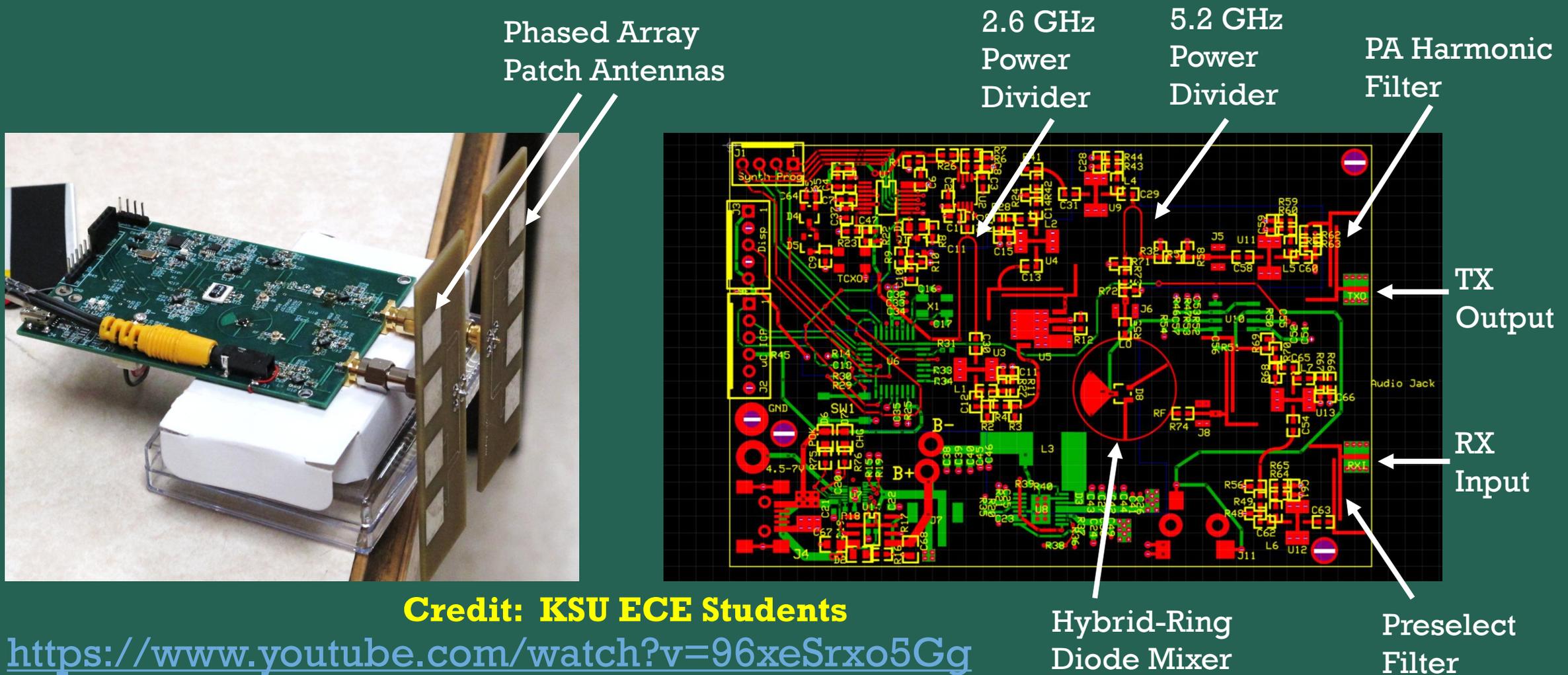
[1] *As described in the course syllabus, this project is worth up to 45% of your grade (15% prelim and 15% writeup on your own part, plus 15% dependent on how successful you company's product is.

Simplified Block Diagram

A block diagram of the three main subsystems (and optional frequency synthesizer) connected together to form the complete doppler radar is shown below together with interface specifications. Note that circuit details are not shown and detailed design procedures are not given. For example, additional amplifiers, power slitters, and/or pads may be needed in a given component. It is up to you to work out details by carefully studying the device data sheets and radar-system specifications, and thinking carefully about what you are doing!
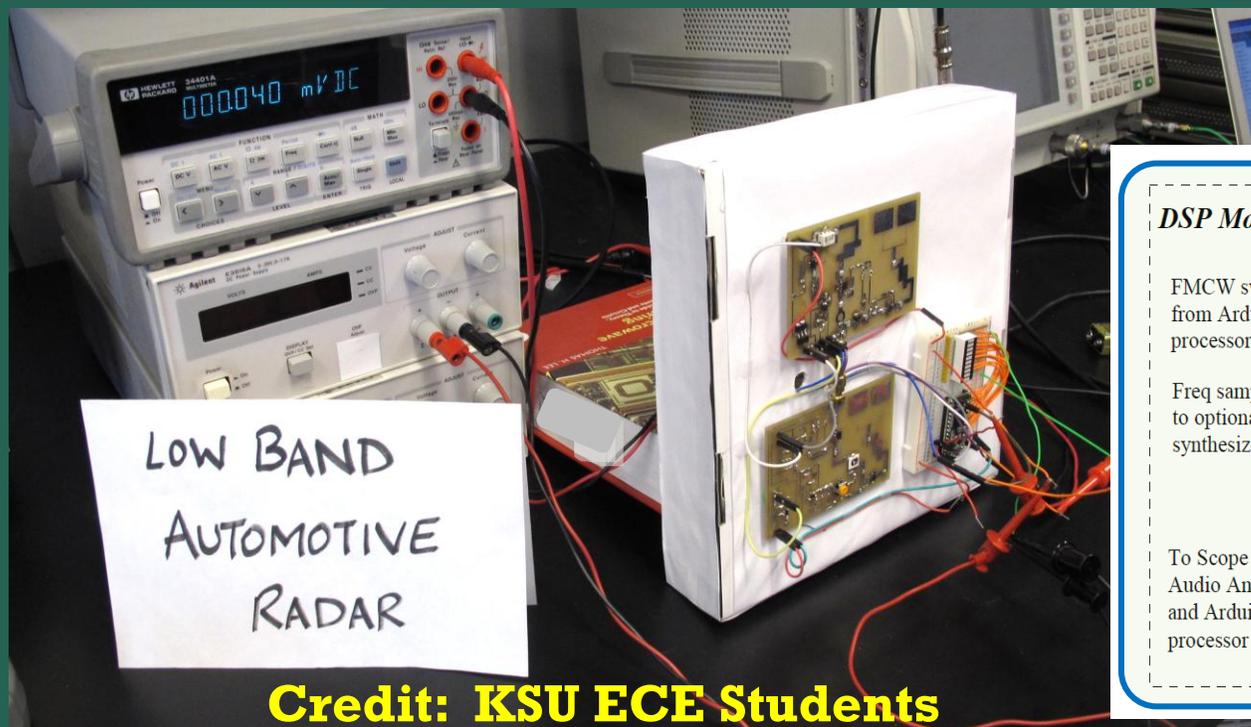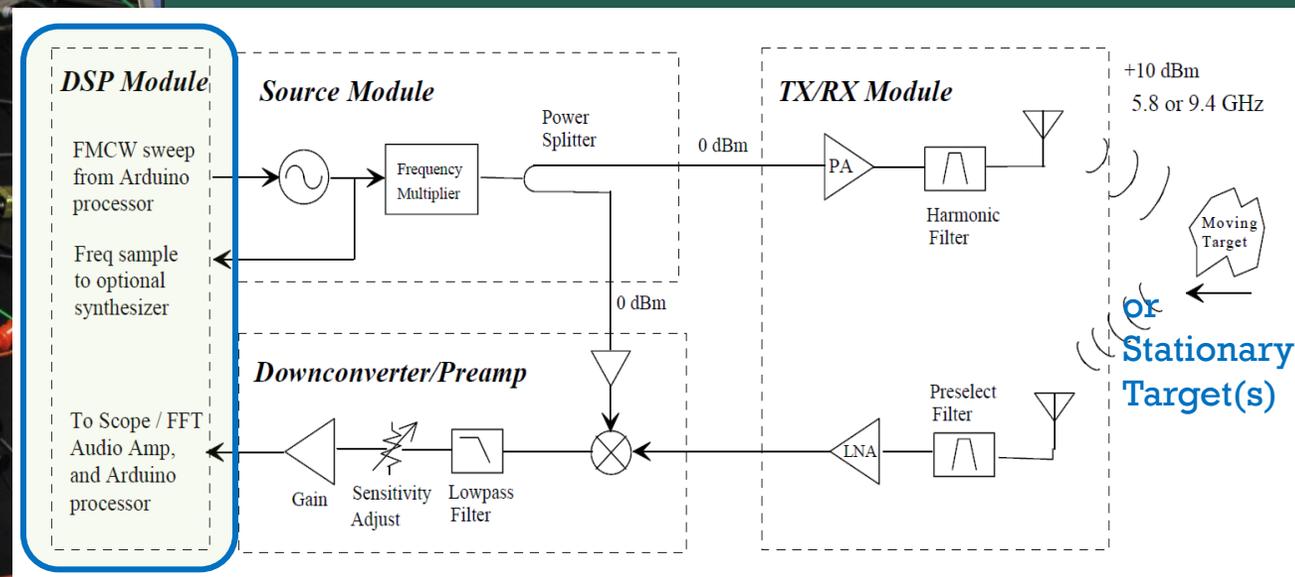
Microstrip Circuits and PCB

Phased Array Patch Antennas
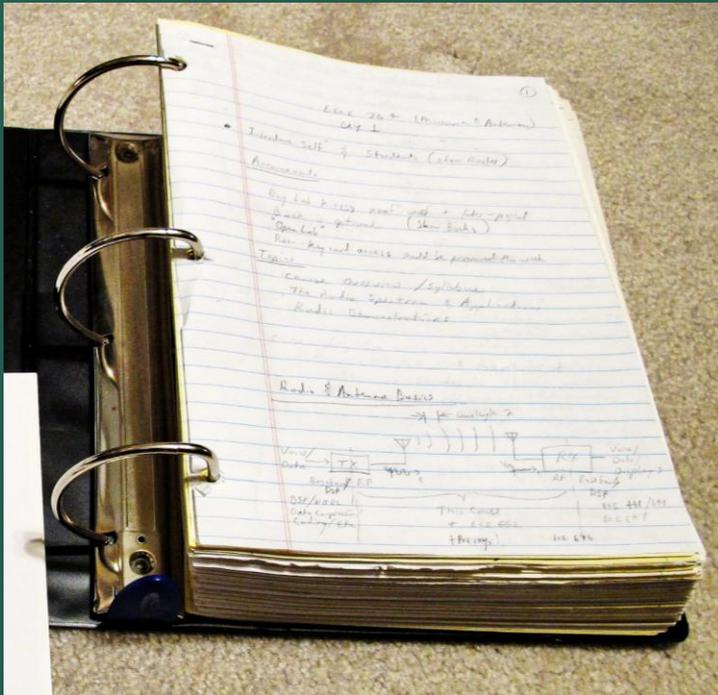
2.6 GHz Power Divider

5.2 GHz Power Divider

PA Harmonic Filter

TX Output

RX Input

Hybrid-Ring Diode Mixer

Preselect Filter

Credit: KSU ECE Students

https://www.youtube.com/watch?v=96xeSrxo5Gg

MegawattKS - YouTube

https://ecefiles.org

Project at 5.8 GHz:
FMCW Radar
(with Indoor Clutter Reduction)

LOW BAND AUTOMOTIVE RADAR

Credit: KSU ECE Students

DSP Module

FMCW sweep from Arduino processor

Freq sample to optional synthesizer

To Scope / FFT Audio Amp, and Arduino processor

Source Module

Frequency Multiplier

Power Splitter

0 dBm

TX/RX Module

PA

Harmonic Filter

+10 dBm
5.8 or 9.4 GHz

Moving Target

or Stationary Target(s)

Downconverter/Preamp

Gain

Sensitivity Adjust

Lowpass Filter

0 dBm

LNA

Preselect Filter

Associated Lectures (Tx lines)

Associated Lectures (and project PCB)

Lambda/4 bias line at 2.9 GHz

5.8 GHz Bandpass Filter
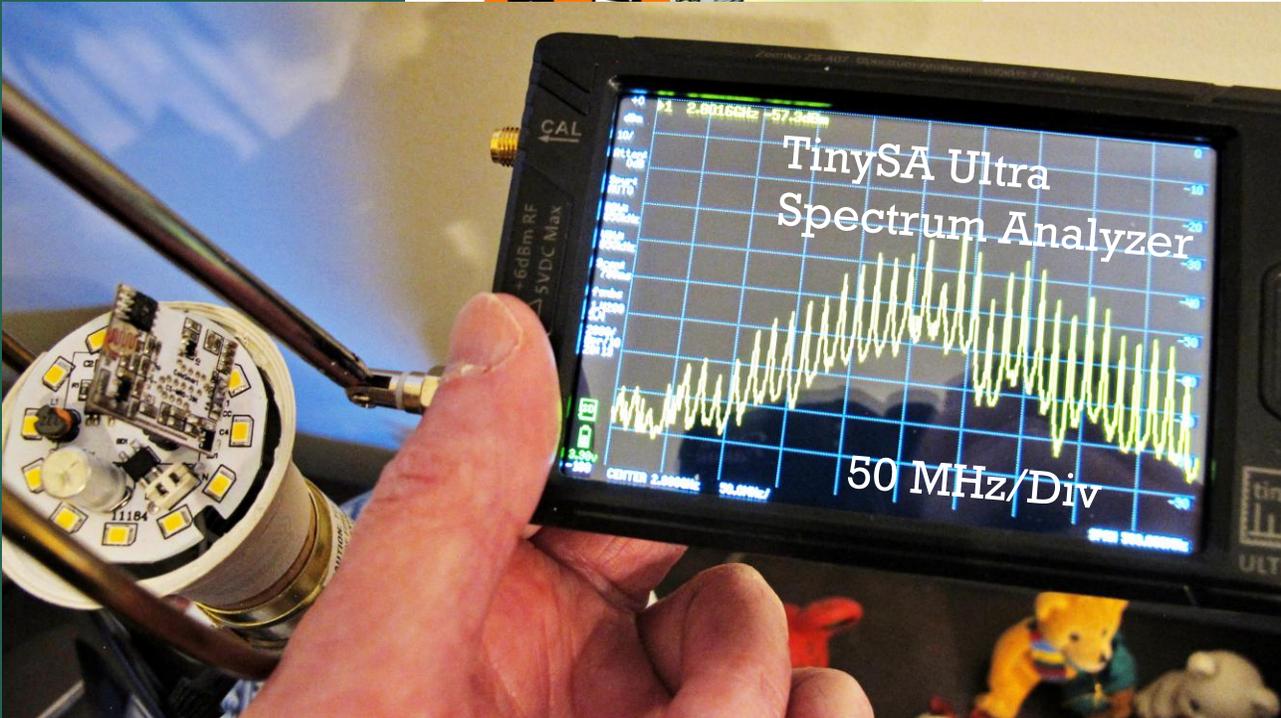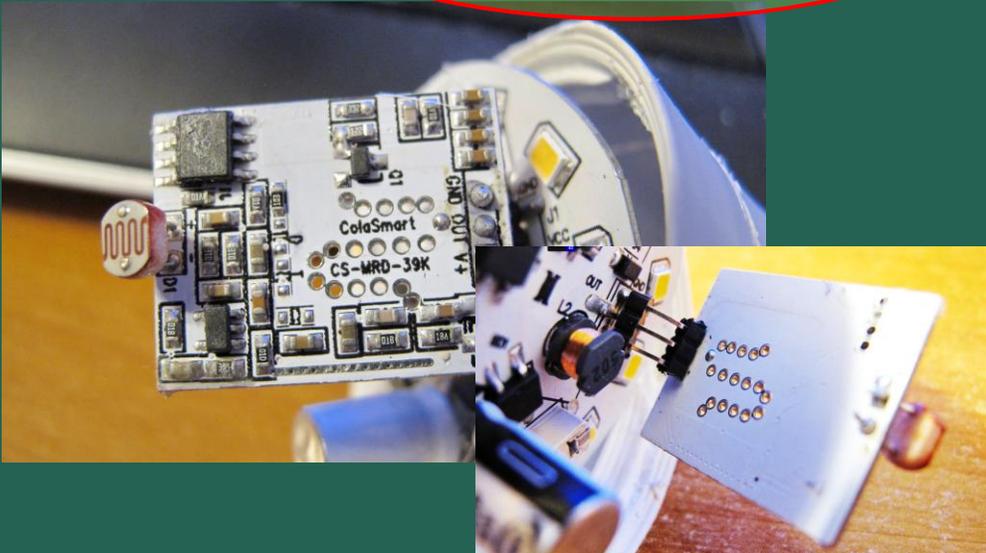
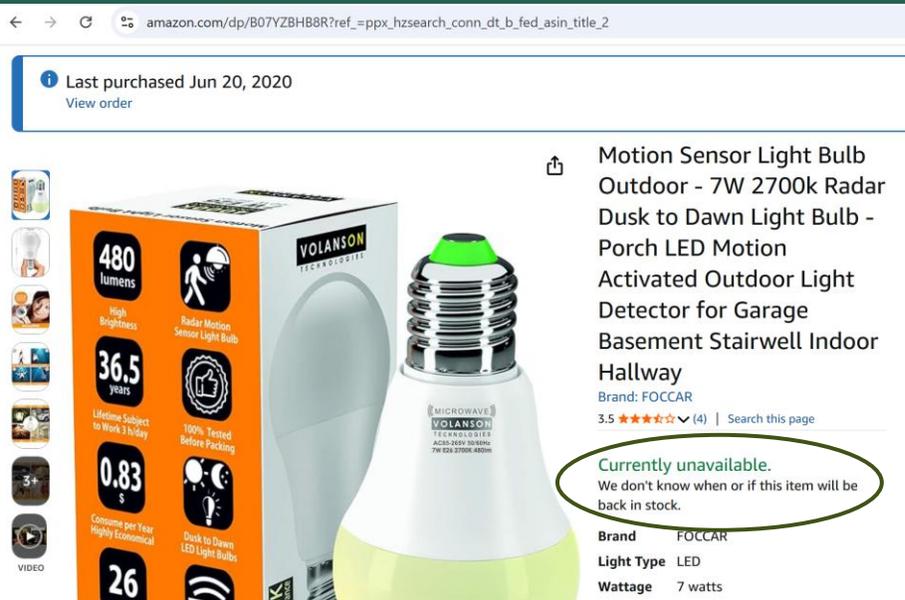5.8 GHz Wilkinson Power Divider
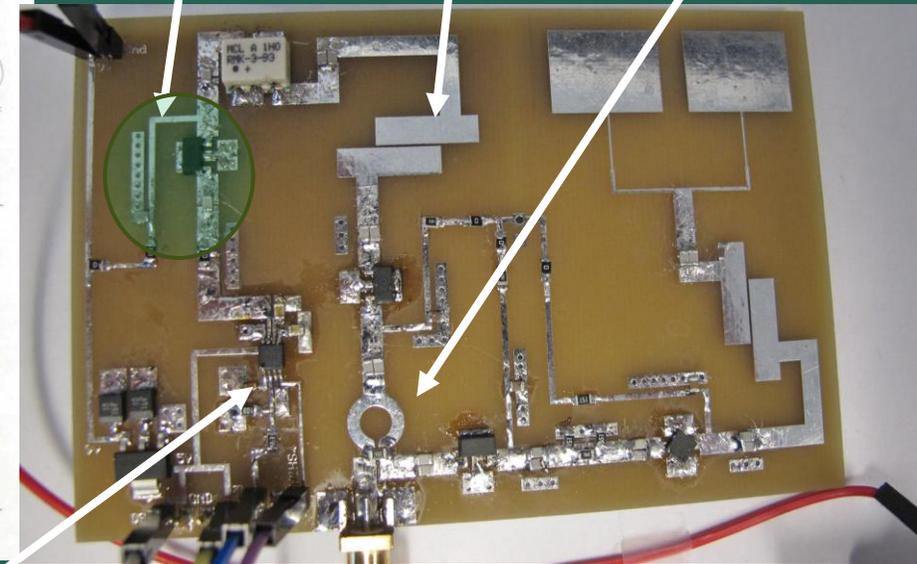
2.9 GHz VCO

Credit: KSU ECE Students

Commercial Product Teardown 1:

2.8 GHz Radar in Lightbulb

(Microwave frequency ?)

CAUTION !

(Exposed High Voltages)

Motion Sensor Light Bulb Outdoor - 7W 2700k Radar Dusk to Dawn Light Bulb - Porch LED Motion Activated Outdoor Light Detector for Garage Basement Stairwell Indoor Hallway

Brand: FOCCAR

3.5 ★★★☆ (4)   Search this page

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Brand	FOCCAR
Light Type	LED
Wattage	7 watts

TinySA Ultra Spectrum Analyzer

50 MHz/Div

CofaSmart
CS-MRD-39K

Commercial Product Teardown 2:
10 GHz LNB for Satellite TV
(definitely microwave)

Commercial Product Teardown 3:
2ⁿᵈ Gen Bosch Automotive FMCW Radar for ACC
(77 GHz – definitely microwave!)
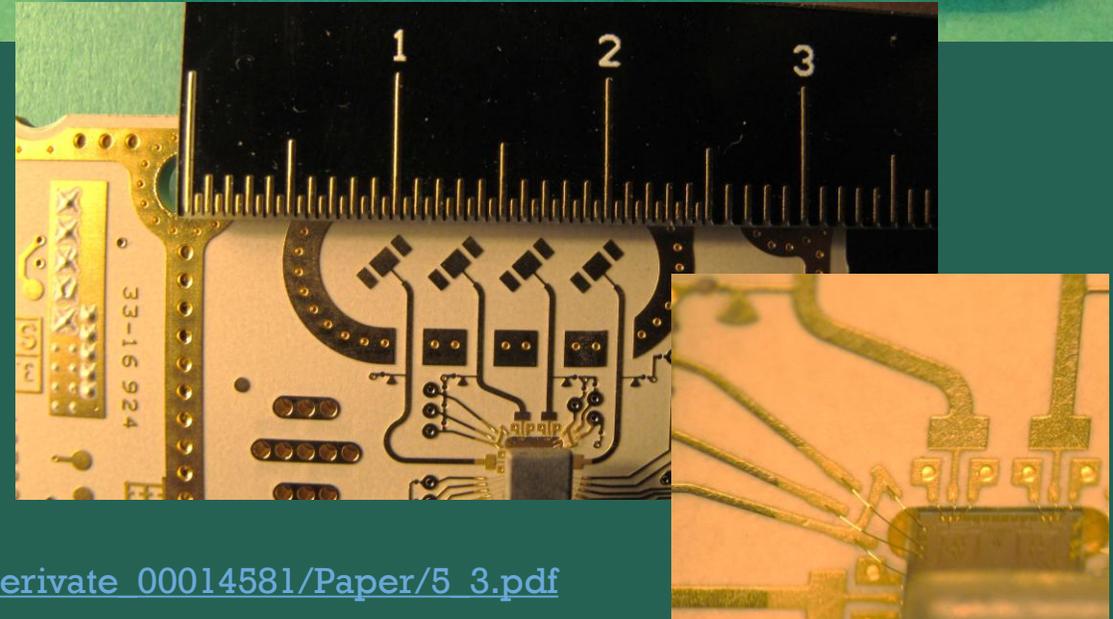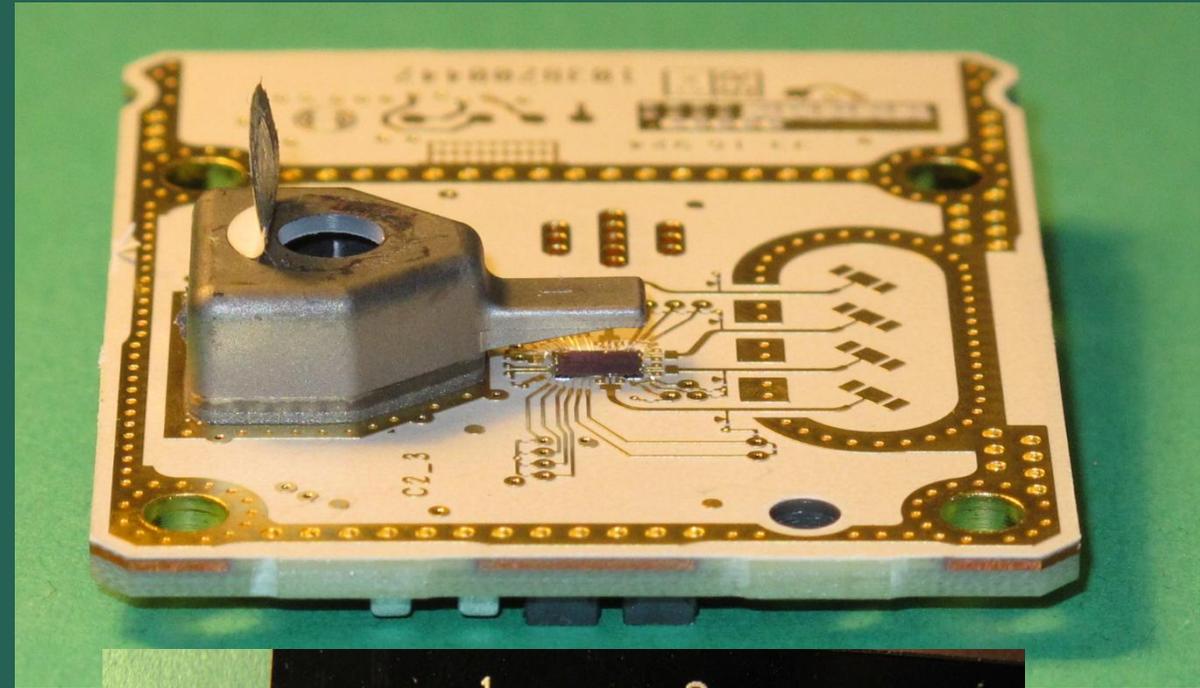
See: "Automotive Radar – Status and Trends", Martin Schneider

https://duepublico2.uni-due.de/servlets/MCRFileNodeServlet/duepublico_derivate_00014581/Paper/5_3.pdf

MegawattKS - YouTube   https://ecefiles.org

Thanks For Watching !