

Radio Design 201 Microwave Circuits and Antennas

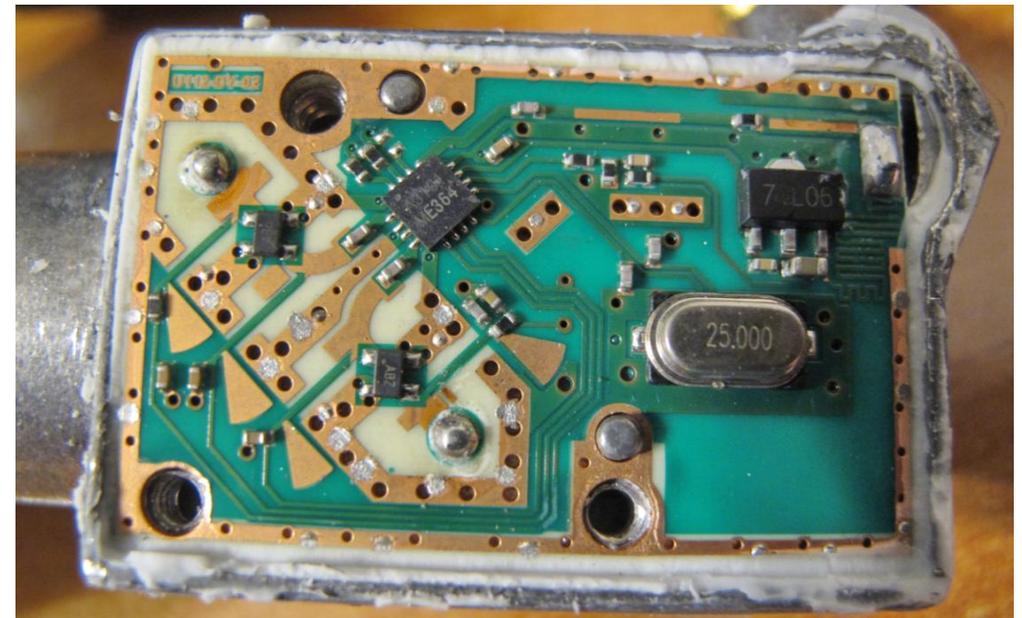
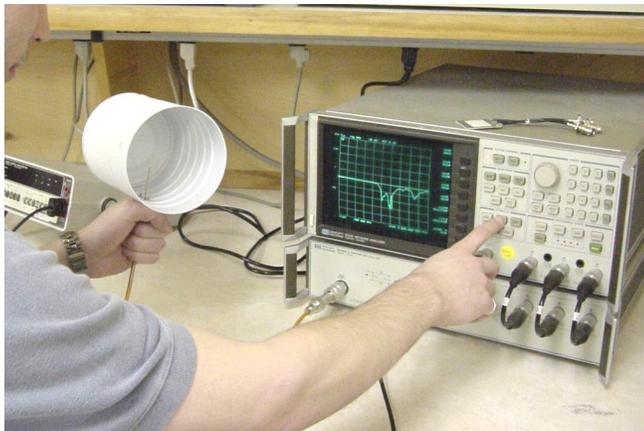
Episode 2 - Project and Product Examples

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

Companion videos at: <https://www.youtube.com/playlist?list=PL9Ox3wpmB0kpOb7NdpHAK-jDpsZm3Xedx>

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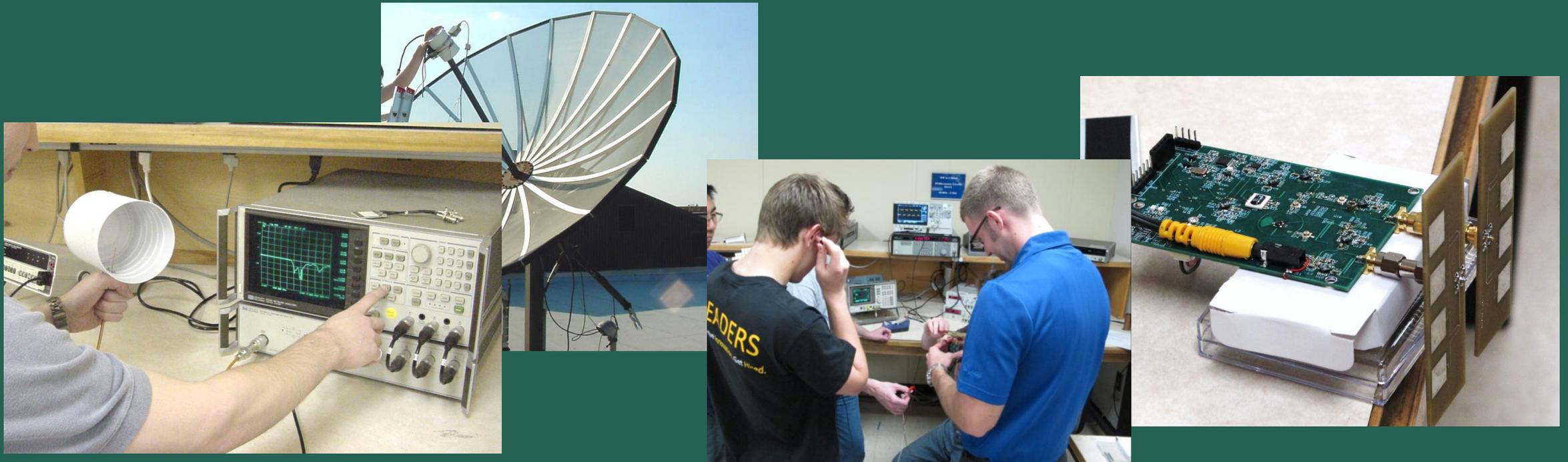
In this second episode of Radio Design 201 we show some of the projects done in a university course on Microwave Circuits and Antennas, as well as some commercial products. Projects and products include satellite ground station receivers, Doppler and CWFM radars for automobiles, and commercial LNBS. 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

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

Speed of Light

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

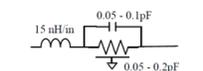
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Component Parasitics at RF

Resistors

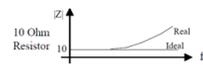


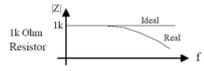
Ideal Model: 

Model at RF: 

Impedance vs Frequency:



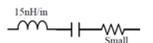
10 Ohm Resistor: 

1k Ohm Resistor: 

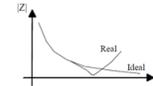
Capacitors



Ideal model: 

Model at RF: 

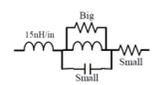
Impedance vs. Frequency:



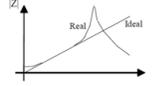
Inductors



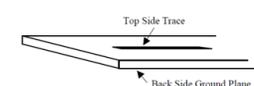
Ideal Model: 

Model at RF: 

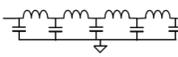
Impedance vs Frequency:



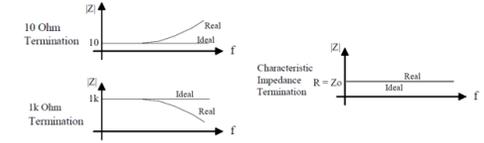
PC Board Trace

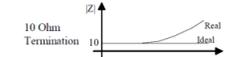


Ideal Model: 

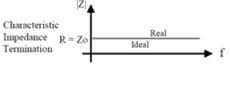
Model at RF: 

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



10 Ohm Termination: 

1k Ohm Termination: 

Characteristic Impedance Termination $R = Z_0$: 

PCB traces, wires, etc are transmission lines at "high frequency".

Important if length is $> 1/10$ wavelength

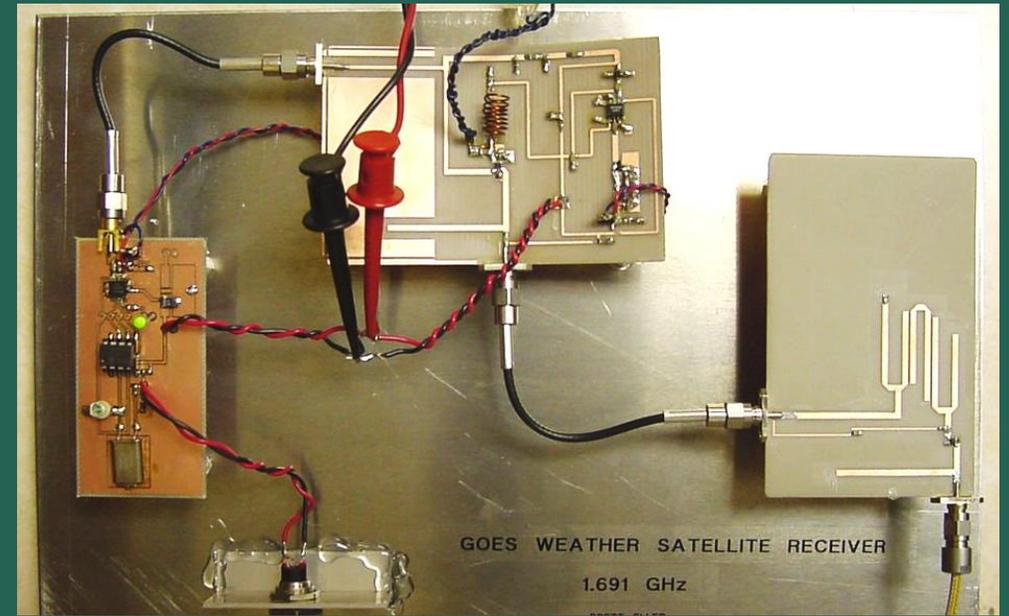
$$\lambda = \frac{c}{f} v_r$$

$$v_r \sim 0.5$$

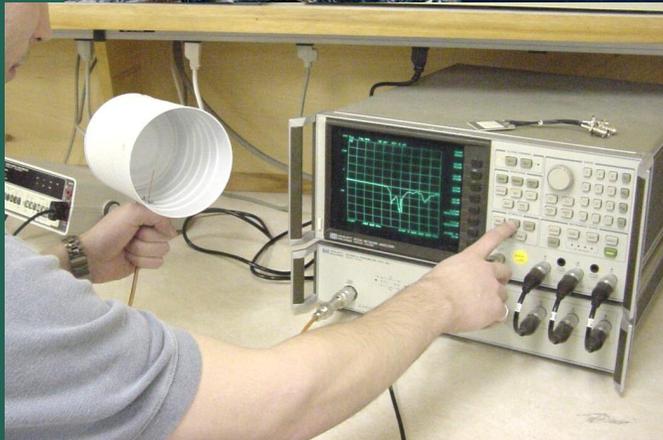
$$\Rightarrow \frac{\lambda}{10} \approx 1.5 \text{ cm at } 1 \text{ GHz}$$

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

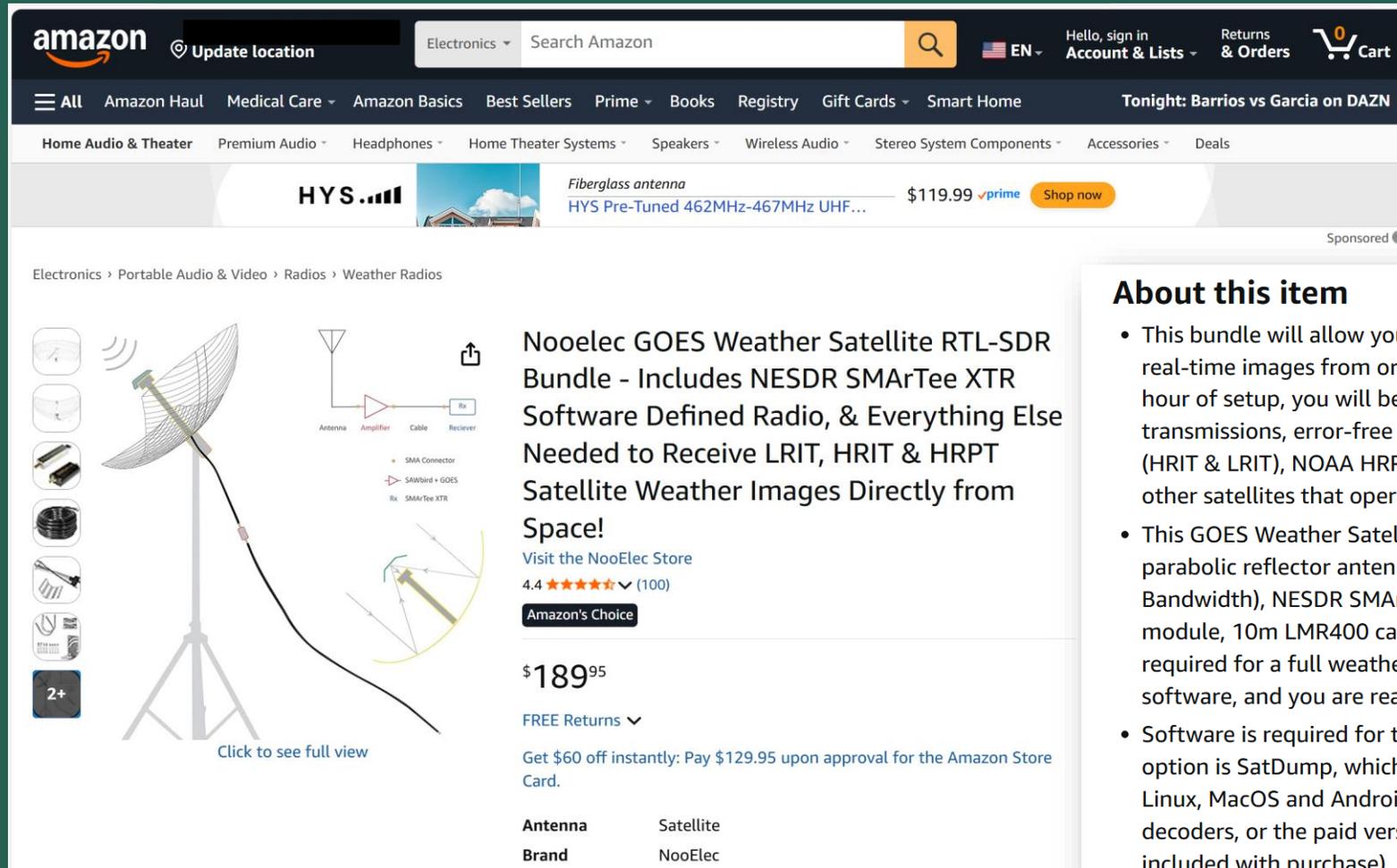


Credit: KSU ECE Students

[MegawattKS - YouTube](#)

<https://ecefiles.org>

2026 Commercial GOES Satellite Receiver



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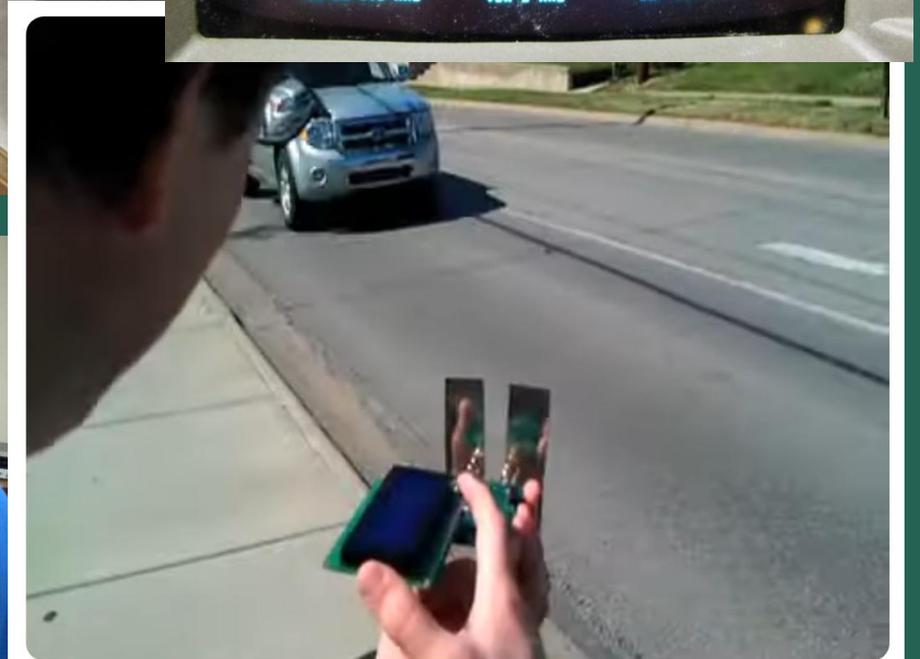
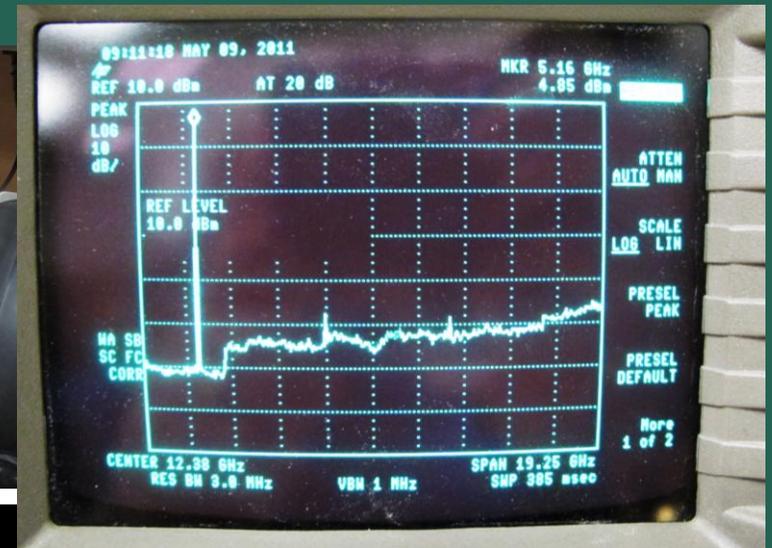
About this item

- This bundle will allow you to receive detailed, high-resolution, near real-time images from orbiting weather satellites. With as little as an hour of setup, you will be receiving LRIT, HRIT and HRPT GOES transmissions, error-free and with ease! Applications include GOES (HRIT & LRIT), NOAA HRPT, Meteor M2 HRPT, Metop, FengYun and other satellites that operate near 1.6GHz-1.8GHz
- This GOES Weather Satellite SDR bundle includes a 21dBi GOES parabolic reflector antenna (1.7GHz center frequency, 200MHz+ Bandwidth), NESDR SMARTEE XTR SDR receiver, SAWbird+ GOES LNA module, 10m LMR400 cable, and the other cables and adapters required for a full weather satellite receiver. Just add a host device and software, and you are ready to go
- Software is required for the decoding of images. The recommended option is SatDump, which is cross-platform and available for Windows, Linux, MacOS and Android. There are also other free Linux-based decoders, or the paid version of XRIT Decoder for Windows (license not included with purchase)

<https://www.amazon.com/Nooelec-GOES-Weather-Satellite-Bundle/dp/B08HGQXC7C/>

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

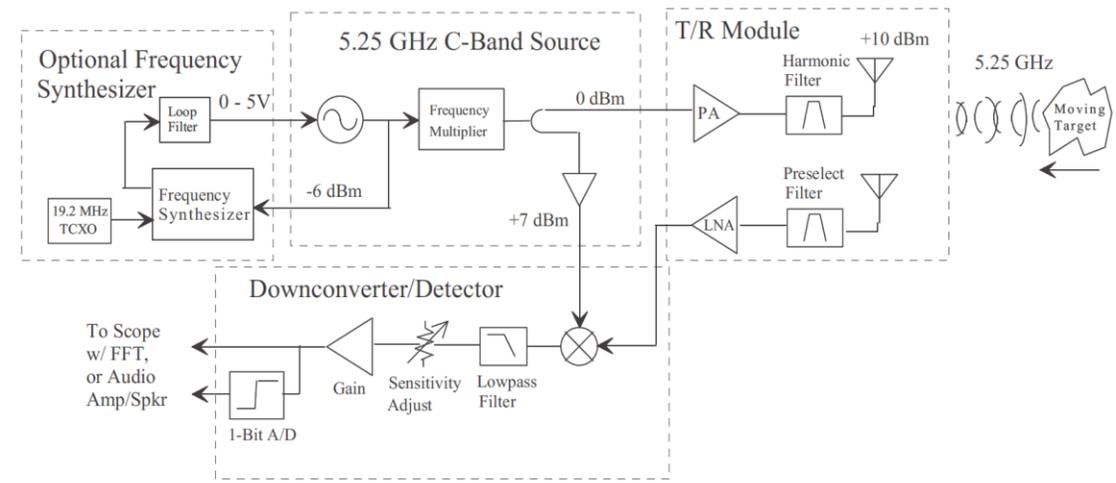
In addition to forming your companies/teams, you should look at the datasheets for the parts you have available and begin work on the designs so that your team/company agree on the gain and power levels at various points in the radar. Some suggested levels are given in the block diagram on the next page, 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 at 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 independently (THIS IS CRITICAL).

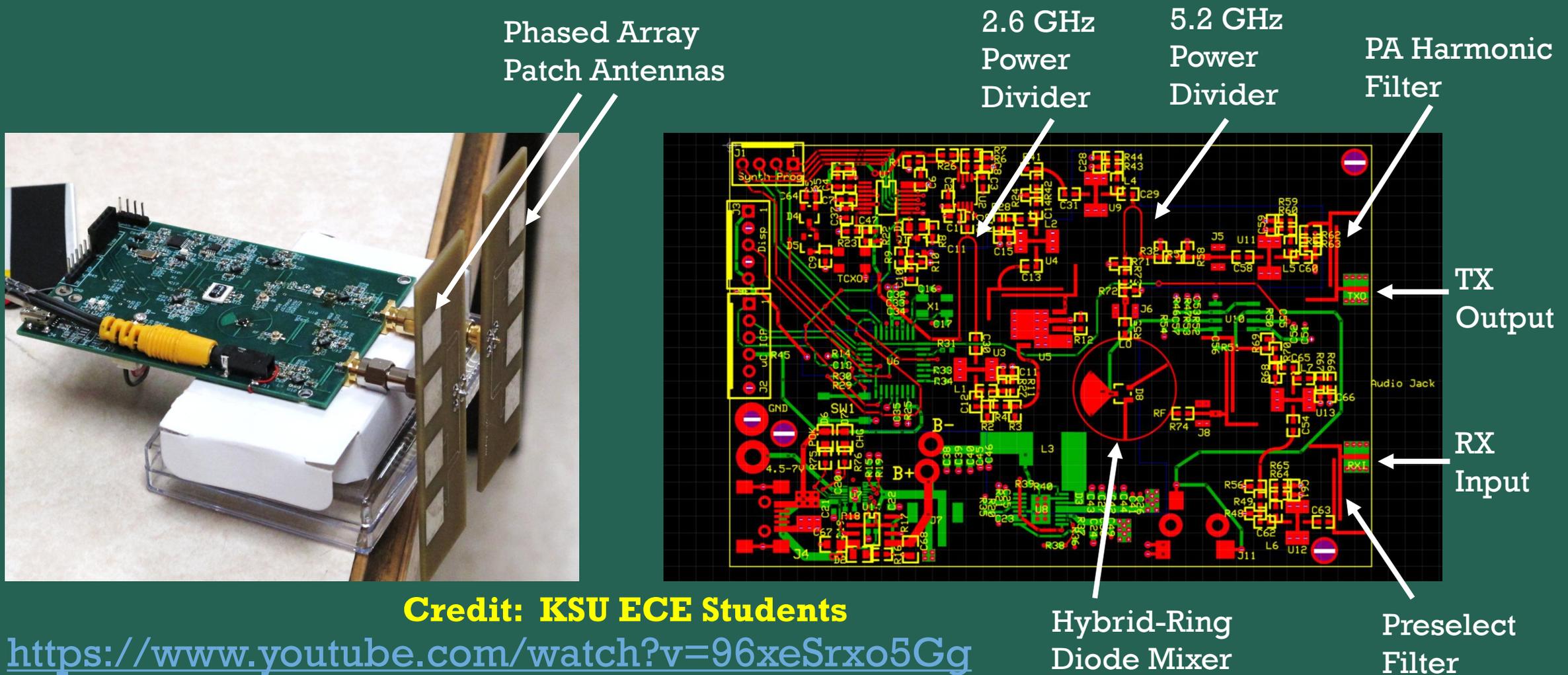
¹ *As described in the course syllabus, this project is worth up to 45% of your grade (15% prelim and 15% writeup on your own part, plus 15% dependent on how successful your company's product is.

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 splitters, 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!



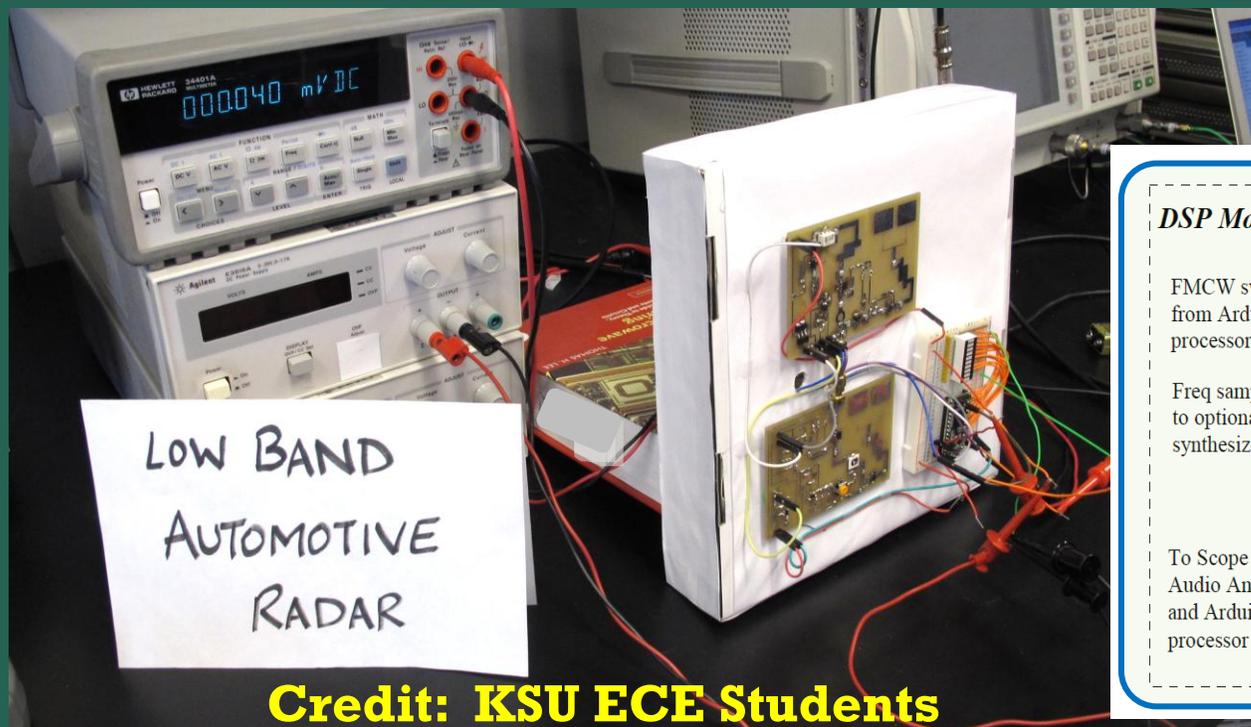
Microstrip Circuits and PCB



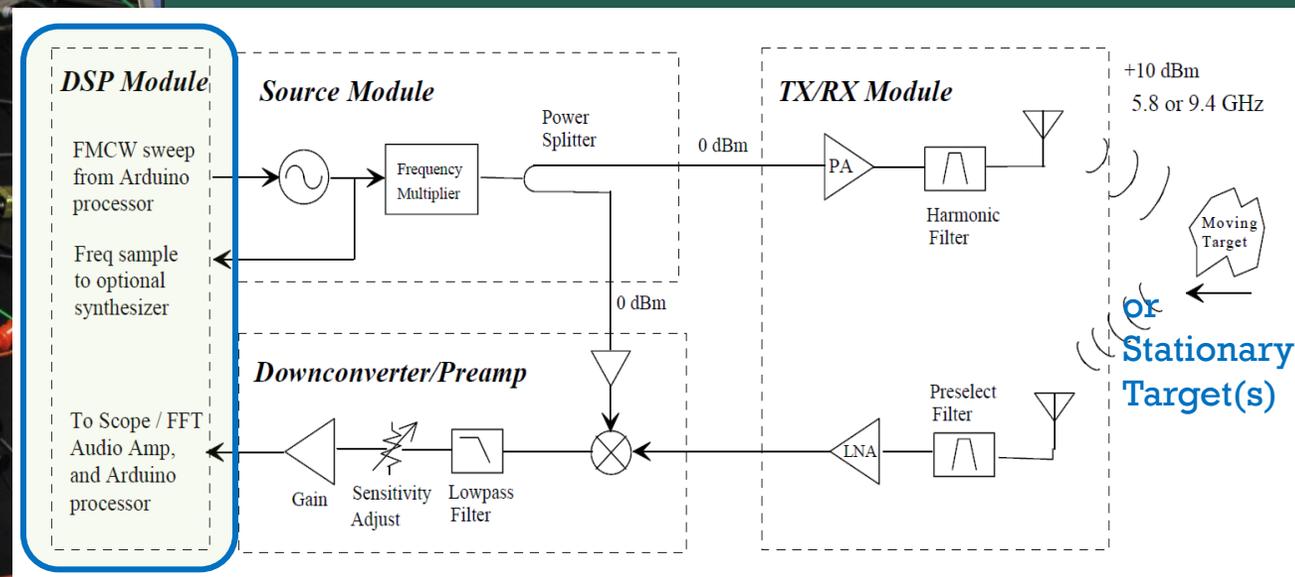
Credit: KSU ECE Students

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

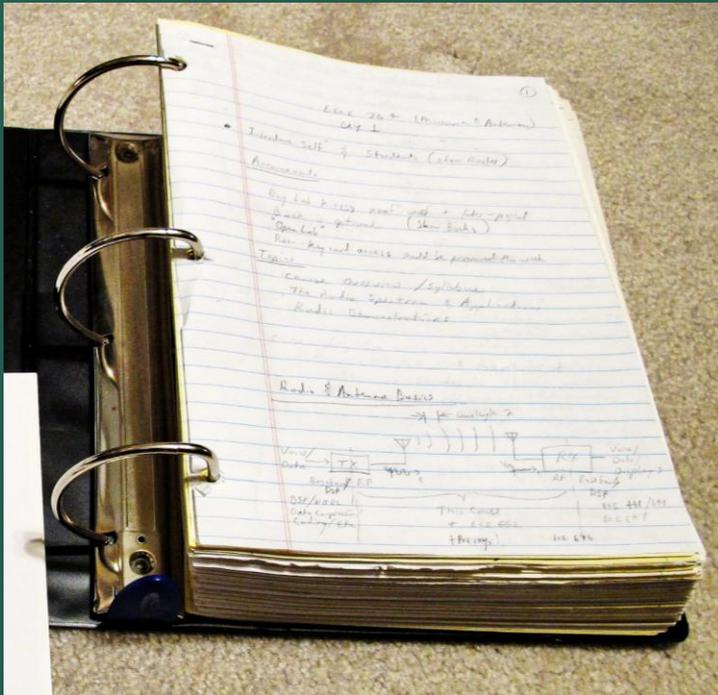
Project at 5.8 GHz: FMCW Radar (with Indoor Clutter Reduction)



Credit: KSU ECE Students



Associated Lectures (Tx lines)



TX Line modeling

COAX OR "TWO-WIRE"

OR PCB "microstrip" trace

$\Delta I = \frac{V}{\frac{1}{j\omega C}} = j\omega C V$ where $\Delta C = C(\Delta X)$ (Typically 1 to 3 pF/inch) C per unit length

$\Delta V = j\omega \Delta L I$ with $\Delta L = L(\Delta X)$ (Typically 5-20 nH/inch)

Current ΔI draws thru ΔC , Voltage "drop" across ΔL (but no power loss if L & C are "lossless" (4, 2 90° apart))

$\Rightarrow V, I$ change ^{phase} along line

\Rightarrow "Guided waves" propagate away from source toward load

IMPORTANT!

At RF & microwave, any "node" $\approx 0.05\lambda$ is NOT a node - it's a complicated LC network!

At 2 GHz $\lambda = \frac{300}{2000} = 0.15\text{ m}$
 $\Rightarrow \lambda/20 = 7\text{ mm} = 1/3\text{ inch}$

Associated Lectures (and project PCB)

Impedance Transformation of TX Lines
(Continued)

Recall
Basic TX Line Setup

Z_L determines reflection coeff. $\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$ w/ $Z = \frac{Z_0}{\Gamma}$
 Solve by get $Z = \frac{1 + \Gamma Z_0}{1 - \Gamma Z_0}$
 Smith chart is mapping of $\Gamma \rightarrow Z$

1) Inlet

Circle of radius $|\Gamma|=1$
 $z=1$ ($\Gamma=0$) at center!
 $z=0$
 $R/Z_0 = 1$
 $X/Z_0 = 0$
 $\Gamma_{in}(z) < 0$ in bottom of chart \Rightarrow capac (Inductive in top half)

To find $Z(-l)$:

- 1) Normalize Z_L to $z_L = \frac{Z_L}{Z_0}$
- 2) Plot point on chart
- 3) Rotate Γ vector by $-720^\circ \frac{l}{\lambda}$ (clockwise)
- 4) Read new $Z(-l)$ value and denormalize $Z(-l) = Z_0 z(-l)$

Important special cases

Z_L	l	Transformer	Result $Z(-l)$
∞	$\lambda/4$		$Z_0!$
0	$\lambda/4$		∞
∞	$< \lambda/4$		$-jX$ (Capacitive!) (Short open line $\Rightarrow \infty \rightarrow 0$)
0	$< \lambda/4$		$+jX$ (An inductor) (Shorted line $\Rightarrow \infty \rightarrow 0$)
∞	$> \lambda/4$ (but $< \lambda/2$)		$+jX$ (inductive)
$R+j0$ w/ $R > Z_0$	$\lambda/4$		$R+j0$ w/ $R < Z_0$
$R+j0$ w/ $R < Z_0$	$\lambda/4$		$R+j0$ w/ $R > Z_0$

Application

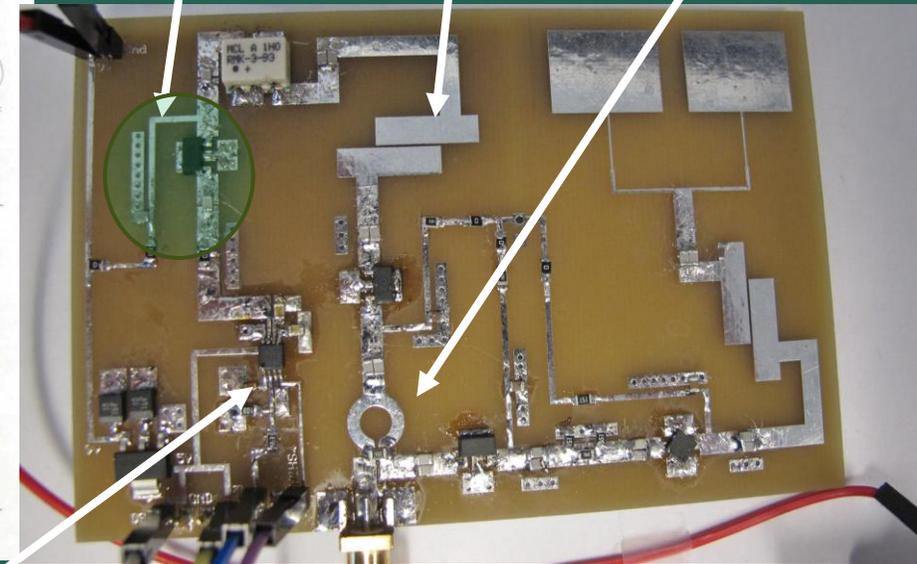
Patch Antenna

Last two cases called "quarter wave impedance transformer"

Lambda/4
bias line
at 2.9 GHz

5.8 GHz
Bandpass
Filter

5.8 GHz
Wilkinson
Power
Divider



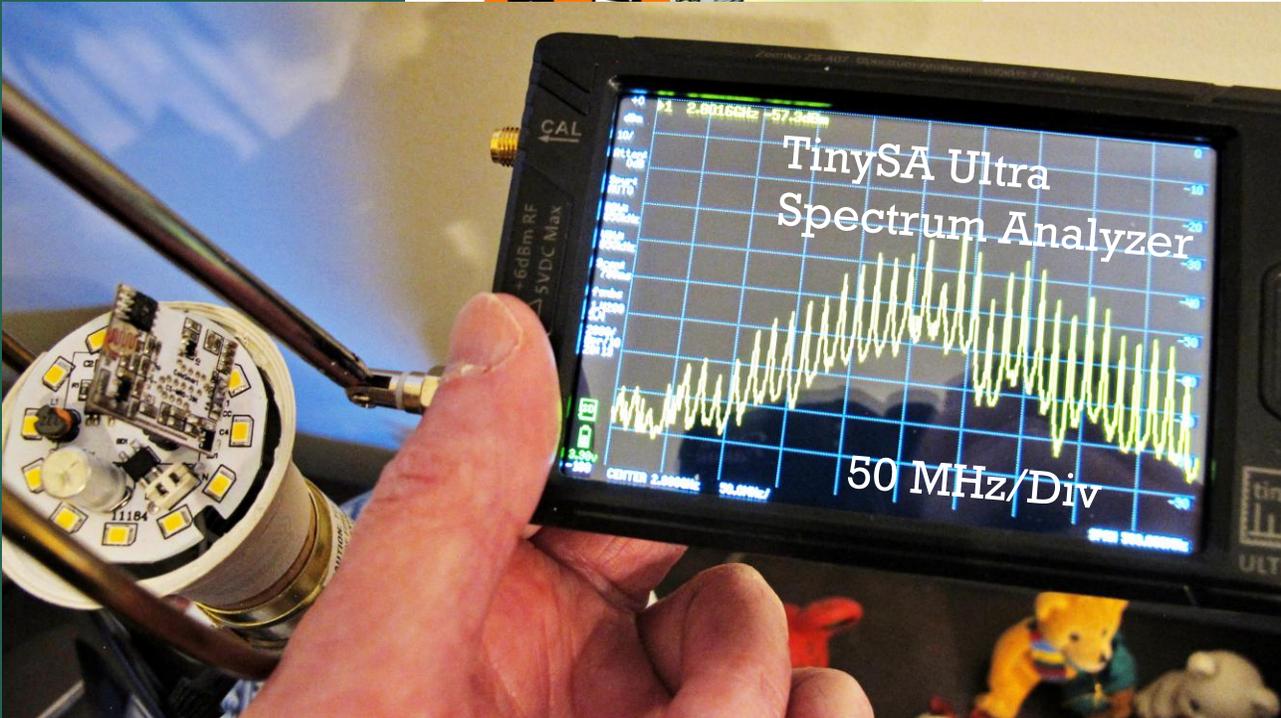
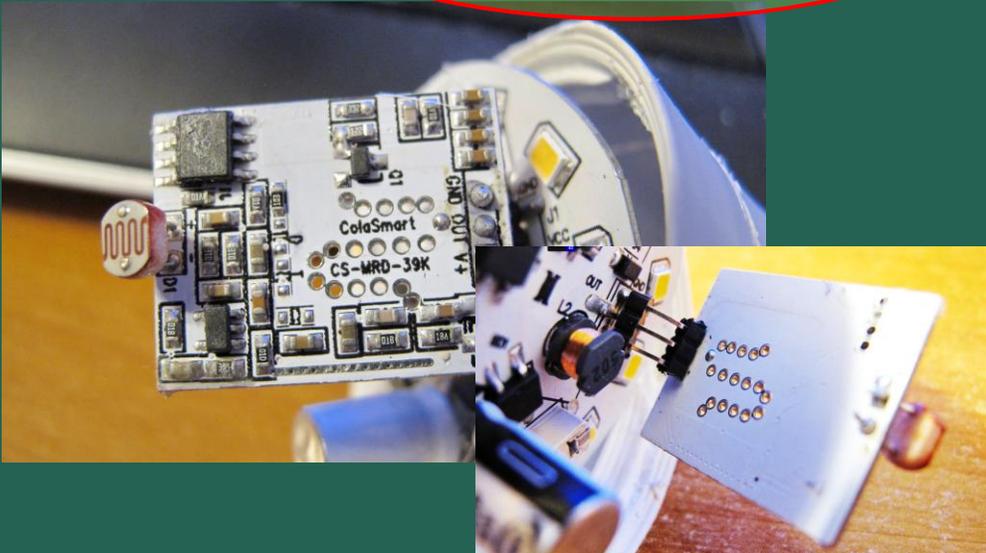
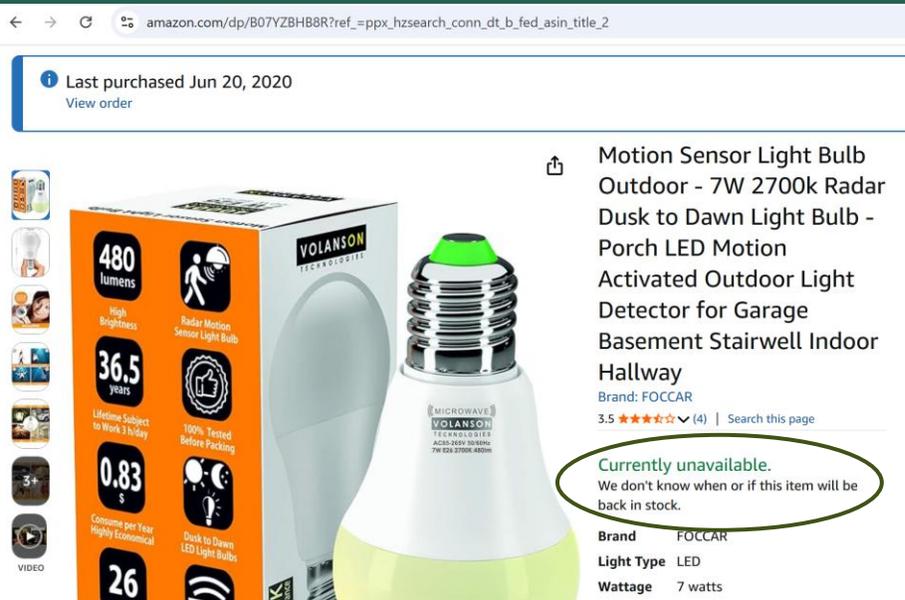
2.9 GHz
VCO

Credit: KSU ECE Students

<https://ecefiles.org>

Commercial Product Teardown 1: 2.8 GHz Radar in Lightbulb (Microwave frequency ?)

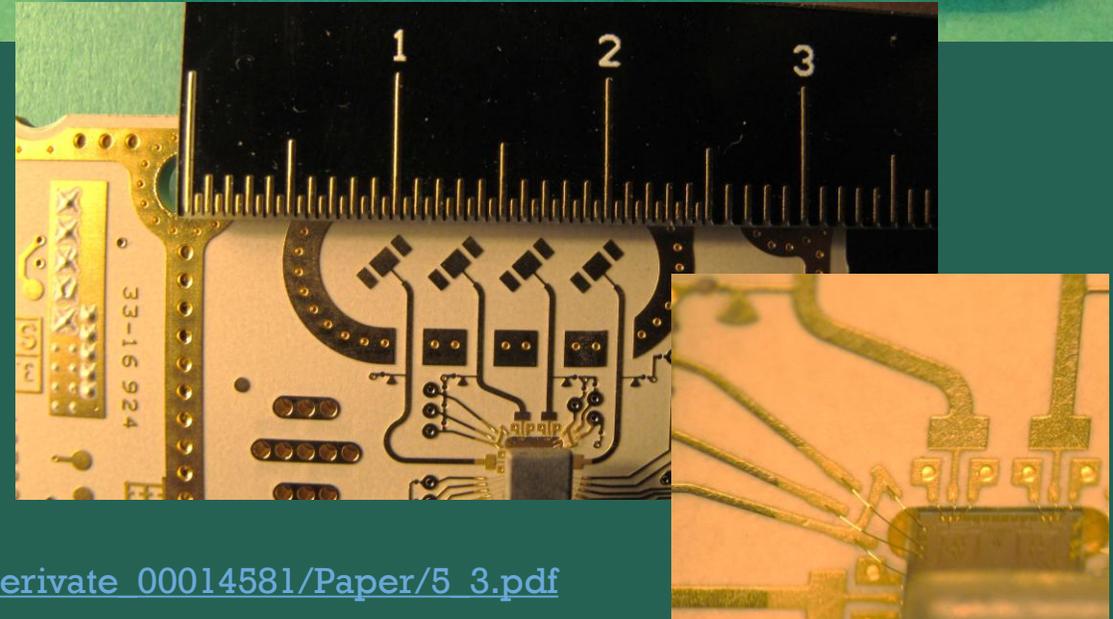
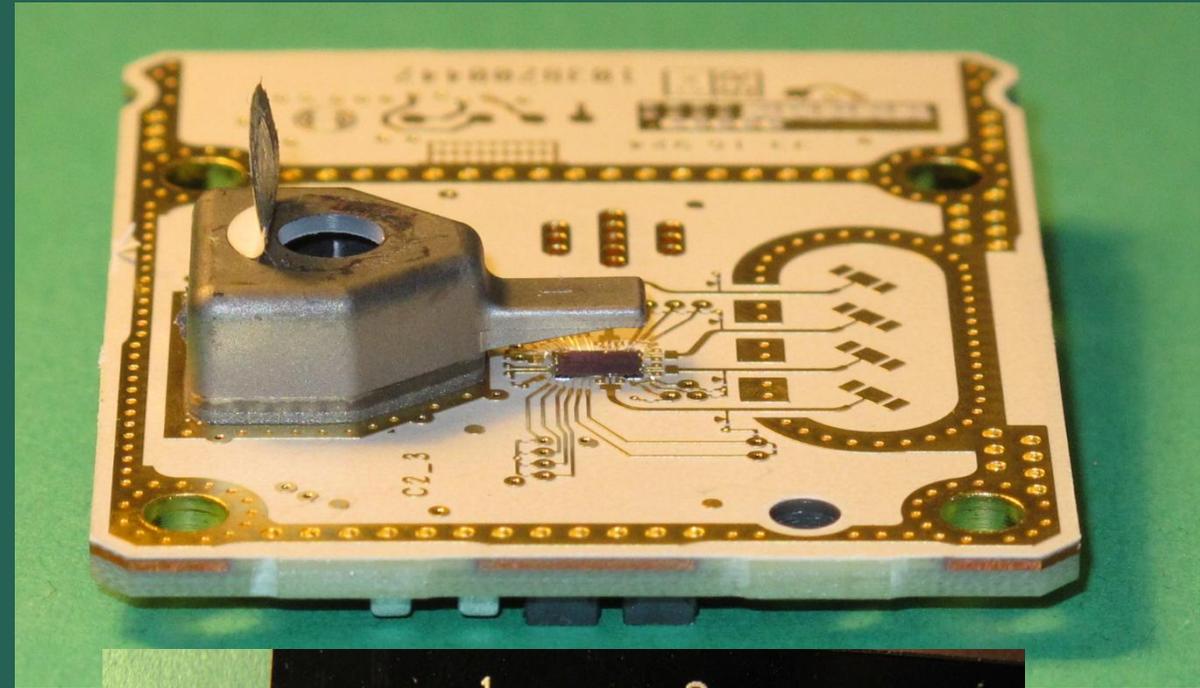
CAUTION!
(Exposed High Voltages)



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

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