

US and ITU Policies for Use of Spectrum Above 100 GHz

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Member of mmWave Coalition
Layman in the Regulatory World

VDI Corporate Facts

- World's leading mmWave and THz Test and Measurement and Components company
- Privately held
- Thousands of systems in the field
- Hundreds of customers in over 40 countries
- Channel partners with Keysight
- Distributors in many countries around the world



VDI Corporate Facts

Year	1996	2004	2020
Number of Employees	2 part time	≈ 10 full time	85 full time
Location and Physical Size	Leased time and space at UVA	3000 sq ft and leased UVA lab space	25k sq ft for all operations including microelectronics
Product Offering	Diodes	Diodes and Components	Diodes, Components, Custom and Standard Systems

I'm going to talk about policy ...

... but first, a story.

Things

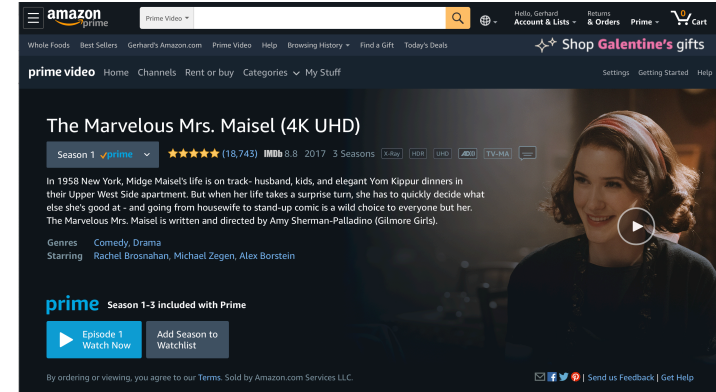


Things on
the Internet



I like ...

The Internet



But Most Favorite Thing that
is on the Internet is ...

My Car



Other People Like My Car Too



#1 electric vehicle,

Exclusives EV Reviews EV News Tesla News

Tesla Model 3 Dominates US Premium-Class Small & Midsize Car Market — 23% of 2019 Sales*

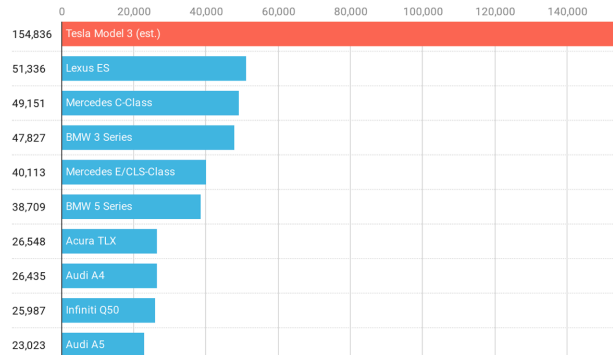
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January 18th, 2020 by [Zachary Shahan](#)

Small & Midsize Luxury Cars — 2019 (USA Sales)



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Convenient in-home pickup
when you donate to good.

Tesla overtakes Volkswagen as value hits \$100bn

22 January 2020



Share

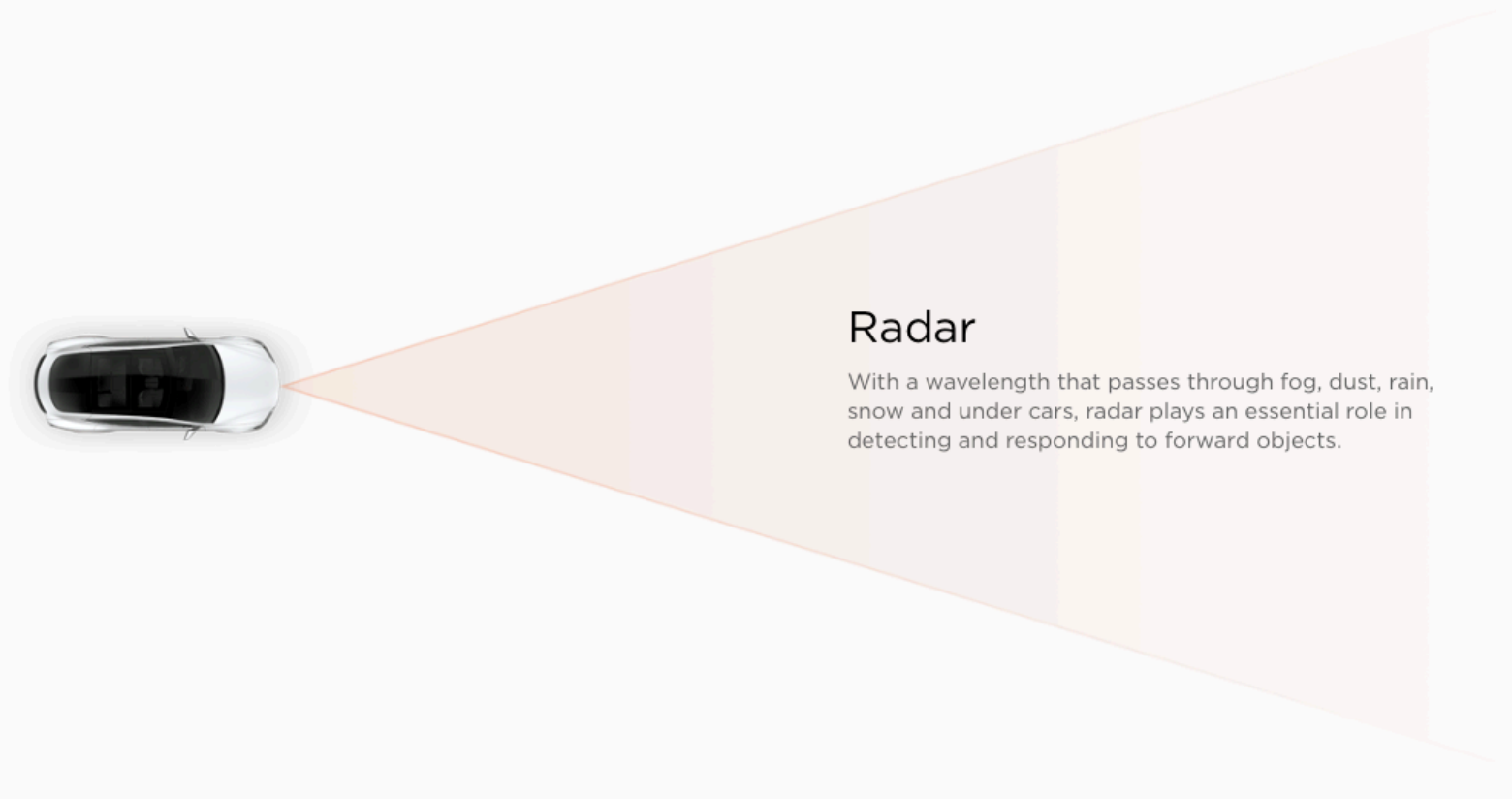


Tesla has displaced Volkswagen as the world's second most valuable carmaker, after a dramatic rise in share price pushed its market value to more than \$100bn (£76.1bn).

Why Do I Like My Car?

1. I think it looks nice
2. It accelerates quickly
3. It occasionally drives itself
4. Most importantly ...
... it has a mmWave radar!

Car Sensors Including Radar



What Radar does it Have?

TMC TESLA MOTORS CLUB

HOME COMMUNITY GROUPS CLUBS VENDORS CONFERENCE

FORUMS WHAT'S NEW NEW POSTS BEST POSTS MEMBERS MEDIA

luntiks, Mar 9, 2019 #1

Warning: Nerdy-nerdnerdynerd thread

Click this image to show the full-size version.



Continental ARS410 radar sensor

So what you're looking at is Tesla's forward radars; AP1, AP2.0 and AP2.5 respectively. (OK, not 100% precise but close enough.)

Radar - Autopilot hardware 2.5 (Continental)

Tesla Model 3, and S/X with Autopilot hardware 2.5 (built since ~August 2017), have a **Continental ARS410 radar sensor**. Tesla part no. 1108647-00-D.

Continental 2-Wheeler EN News Press Career Company

Safe Mobility

Advanced Radar Sensor 410

Choose Vehicle Type

Safe Mobility	Intelligent Mobility	Tires	Engineering Services
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Home > Safe Mobility > Sensors > Advanced Radar Sensor 410

Advanced Radar Sensor 410

Overview Specifications Benefits Contact Us

Continental 2-Wheeler EN News Press Career Company

Safe Mobility	Intelligent Mobility	Tires	Engineering Services
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Advanced Radar Sensor 410

Overview Specifications Benefits Contact Us

Technical Specifications

- > Range up to 170m
- > Field of View (Near +/-45°, Mid. +/-9°, Far +/-4°)
- > Speed Range ACC Follow to Stop up to 170km/h
- > Dimensions: 94 x 69 x 20 mm
- > Mass: 130 g
- > Update rate: 50 ms
- > Speed meas. acc. ± 0.1 kph
- > Temp. Range: -40° to +85°
- > Power Dissip.: 4.5 W
- > Supply Voltage: 12V and 24V
- > Operation Freq.: 76..77 GHz

76 – 77 GHz



Where do the ICs come from?



SYSTEM AUTOMOTIVE



Continental ARS4-A 77GHz Radar

Published	14/03/2017
Product code	SP17321
Price	EUR 2 990
Applications	Automotive

ADD TO CART

Ask for info Available Buyer Available sample

Introduction Summary Similar reports

The Continental ARS4-A Radar is designed for forward collision warning, emergency brake assist, collision mitigation, lane change assist, adaptive cruise control. A special feature of the device is the simultaneous measurement of long distances, up to 150m with $\pm 0.2m$ accuracy, and short range, up to 70m, relative velocity and angle between two objects. It is thus able to detect stationary objects without any sensor support.

The system integrates two electronic boards including an NXP Semiconductor microcontroller and Broadcom Ethernet transceiver. The radio-frequency (RF) board is manufactured with an asymmetric structure using a hybrid PTFE/FR4 substrate and is equipped with planar antennas.

The NXP Semiconductor multi-channel 77 GHz radar transceiver chipset, composed of four receivers, two transmitters and an associated voltage controlled oscillator (VCO), is used as high-frequency transmitter and receiver. The RF dies are packaged in redistributed chip package (RCP) fan-out wafer level packages initially developed and manufactured by Freescale.

Based on a complete teardown analysis of the Continental radar, the report provides the bill-of-material (BOM) and the manufacturing cost of the radar sensor.

A complete physical analysis and manufacturing cost estimation of the NXP semiconductor monolithic microwave integrated circuits (MMICs) is available in a separate report.



Analog, Mixed
Signal and Power
Management

MR2001-77 GHz Radar Transceiver Chipset

Our millimeter wave and radar products enable advanced, high-performance, multi-channel systems for use in automotive radar, automotive advanced driver assistance systems (ADAS), automotive safety systems and other high-performance communication infrastructure and industrial systems.

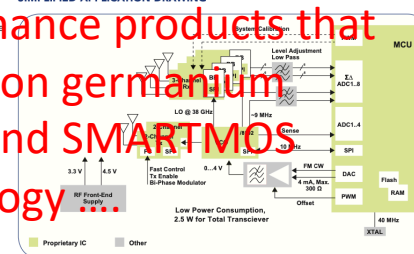


Our company is a leading provider of high-performance products that use silicon germanium (SiGe) and SMARTMOS technology.

and modulation master is a single MCU with integrated high-speed analog-to-digital converter (ADC), 100 processing signal processing capability, such as fast Fourier transforms (FFTs).

ANALOG SOLUTIONS
Expanding on more than 30 years of innovation, our company is a leading provider of high-performance products that use silicon germanium (SiGe) and SMARTMOS technology combining digital, power and standard analog functions. These products and power management solutions are developed for the automotive, consumer, industrial and networking markets. Analog solutions interface with real-world signals to control and drive for complete embedded systems.

SIMPLIFIED APPLICATION DRAWING



Is it Really a mmWave Radar?

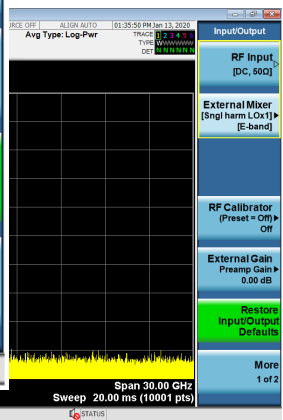
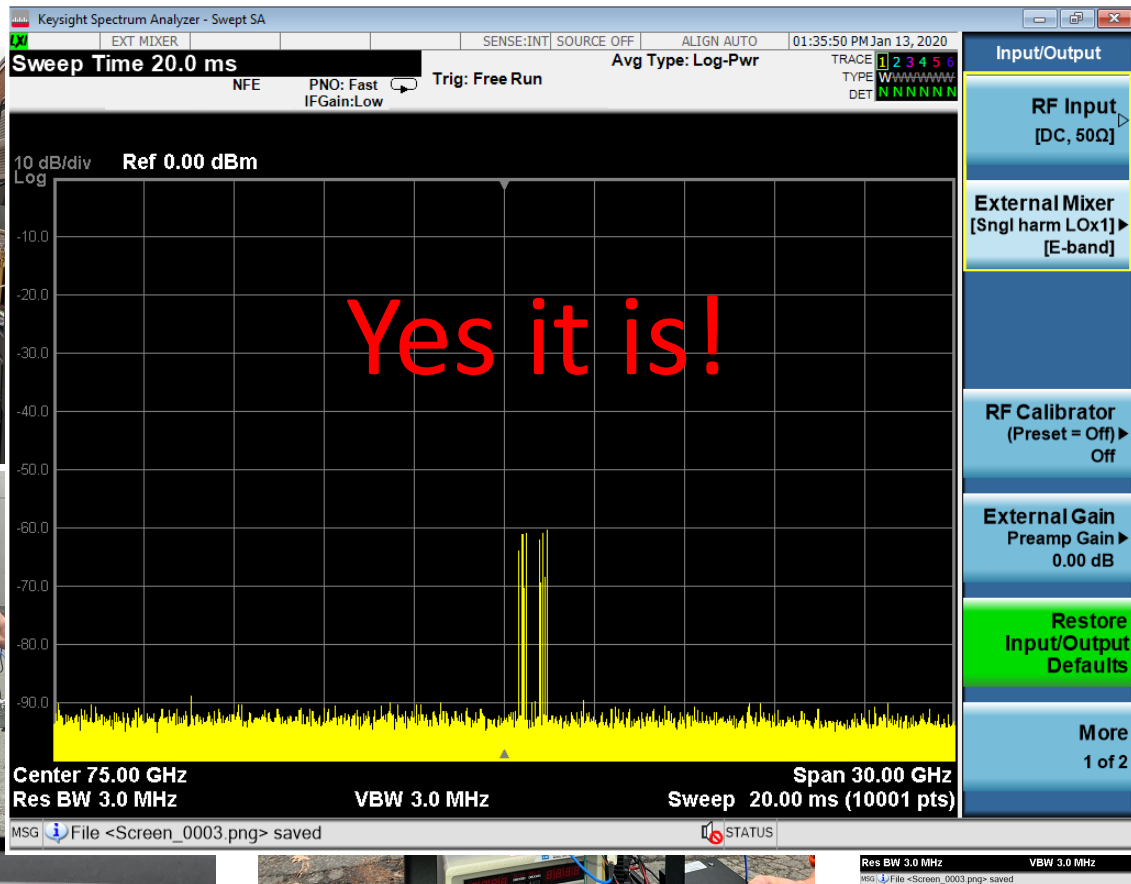


Diagram illustrating the various sensors and their ranges around a vehicle:

- Long Range Radar** (Blue)
- LIDAR** (Red)
- Camera** (Green)
- Short-Medium-Range Radar** (Orange)

Sensors and their associated ranges:

- Adaptive Cruise Control (Long Range Radar)
- Emergency Braking, Pedestrian Detection, Collision Assistance (Camera)
- Lane-Departure Warning (Short-Medium-Range Radar)
- Last Deceleration Warning (Short-Medium-Range Radar)
- Park Assist (Short-Medium-Range Radar)
- Cross-Traffic Alert (Short-Medium-Range Radar)
- Surround View (Long Range Radar)
- Digital Side Mirror (Long Range Radar)
- Environment Mapping (Long Range Radar)
- Blind Spot Detection (Short-Medium-Range Radar)
- Rear Cross-Traffic Warning (Short-Medium-Range Radar)
- Rear Cross-Traffic Alert (Short-Medium-Range Radar)
- Park Assistance, Surround View, Ring View Mirror (Short-Medium-Range Radar)
- Rear Cross-Traffic Warning (Short-Medium-Range Radar)
- Environment Mapping (Short-Medium-Range Radar)
- Digital Side Mirror (Short-Medium-Range Radar)
- Surround View (Short-Medium-Range Radar)
- Environment Mapping (Short-Medium-Range Radar)
- Digital Side Mirror (Short-Medium-Range Radar)
- Surround View (Short-Medium-Range Radar)
- Adaptive Cruise Control (Long Range Radar)

Published on November 8, 2016



5 articles + Follow

Attacking MMW Radar - Setup

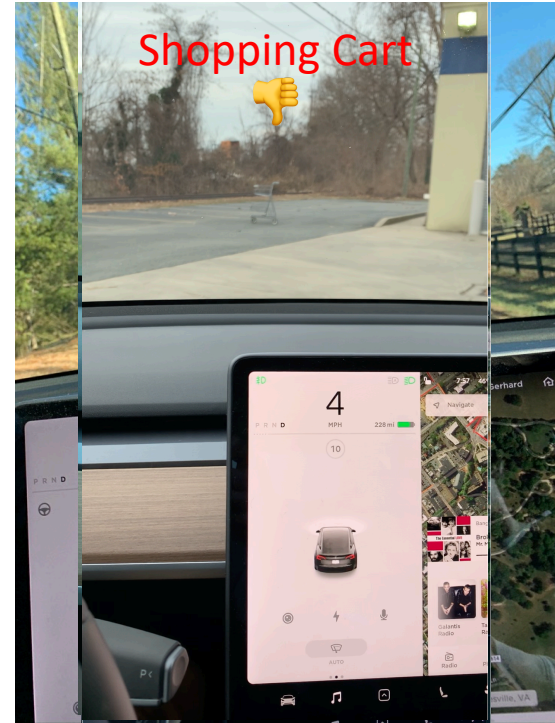
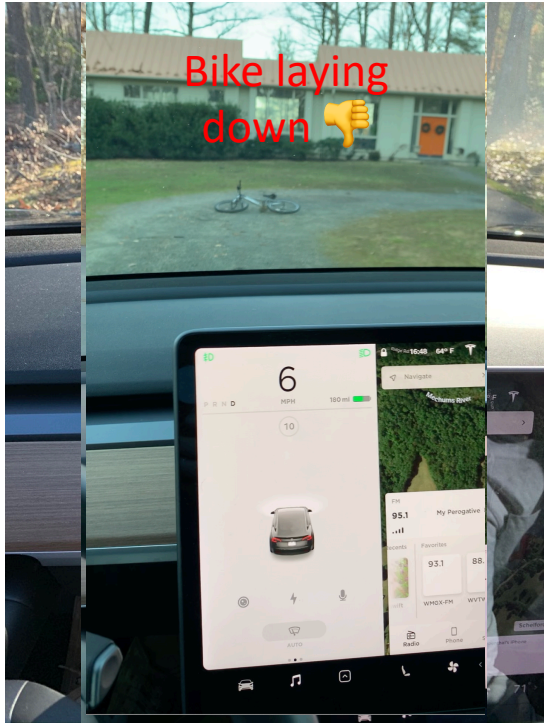
- Signal Analysis
- Jamming Attack
- Spoofing Attack

Equipment:

- Tesla Model S Radar (A)
- Signal analyzer (C)
- Harmonic mixer (E)
- Oscilloscope (B)
- Signal generator (D)
- Frequency multiplier (F)



But What Does it Really See?



And the Car Did not See the Deer!



So We Need More Sensors

- Need to be able to see more targets and more of the environment
- Could be a combination of many sensors
- Optical cameras, LIDAR, ultrasound, radar are all viable candidates
- More sensors are better
- Radar spatial resolution scales with wavelength
- So why not mmWave/THz sensors above 100 GHz?
 $4 \times 70 \text{ GHz} = 280 \text{ GHz}$ – 4 time the spatial resolution
- RadSenseComm - multiple functions on one radio

The mmWave Coalition is Trying to Help

The mmWave Coalition is a group of innovative companies united in the objective of removing regulatory barriers to technologies using frequencies ranging from 95 GHz to 450 GHz. The Coalition does not limit itself to supporting any particular use or technology but rather it is working to create a regulatory structure for these frequencies that would encompass all technologies and all possible uses, limited only by the constraints of physics, innovation, and the imagination.

mmWave Coalition Members

- American Certification Body, Inc.
- Azbil North America Research and Development, Inc.
- Global Foundries, Inc.
- Keysight Technologies
- National Instruments
- Nokia Corporation
- NSI-MI Technologies
- Cubic/Nuvotronics, Inc.
- NYU WIRELESS
- Qorvo, Inc.
- RaySecur
- Samsung Research America Inc.
- VEGA Americas
- Virginia Diodes, Inc.
- VUBIQ Networks
- Would be great to have your organization too!

Caution!

- It is early in game in the formulation of regulations above 100 GHz!
- It will take years to achieve a regulatory framework!

Passive Spectrum Uses Have to be Protected

- Oldest is Radio Astronomy
 - Focus is frequencies with molecular resonances to detect molecules in distant places
 - Observatories for 95+ GHz in high arid places
- Earth Exploration-Satellite Service(EESS)
 - Also focuses on molecular resonances
 - Worldwide coverage from downlooking satellite sensors necessary
 - Includes weather observation

Why mmWave/THz differs from classic spectrum policy assumptions

- Atmospheric absorption in many cases has a big impact on radio propagation
- Small wavelengths permits narrowly focused beams and use of antenna design approaches not practical at lower bands
- Due to high density of molecular resonances mmWave/THz has many bands with passive allocations and special protections

Regulatory Alphabet Soup – Layman's Explanation



- International Telecommunication Union (ITU) is an international/UN organization
- Radio Rules (RR) are a treaty and US is a signatory
- World Radiocommunication Conferences (WRC) meets every 4 years to discuss RRs and other topics
- Federal Communications Commission (FCC) oversees commercial interests in the US
- The National Telecommunications and Information Administration (NTIA) oversees federal government interest in the US
- The FCC issues Notices for Proposed Rulemaking (NPRM) when there is a change to be made

Example of Difference in Regulations



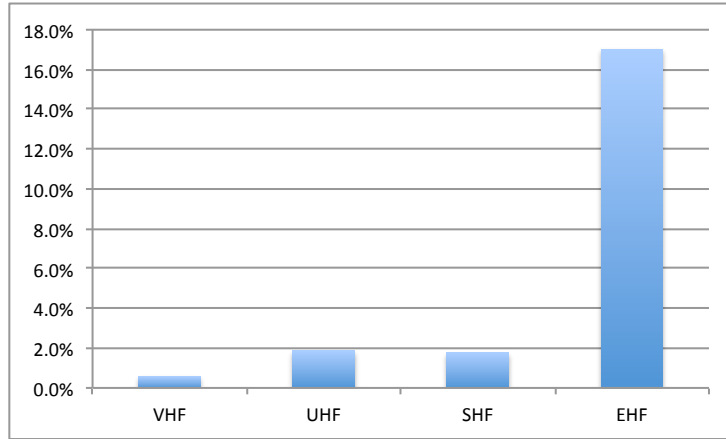
5.340 All emissions are prohibited in the following bands:
..., 100-102 GHz, 109.5-111.8 GHz, 114.25-116 GHz, 148.5-151.5
GHz, 164-167 GHz, 182-185 GHz, 190-191.8 GHz, 200-209 GHz,
226-231.5 GHz, 250-252 GHz. (Allocations <100 GHz omitted)



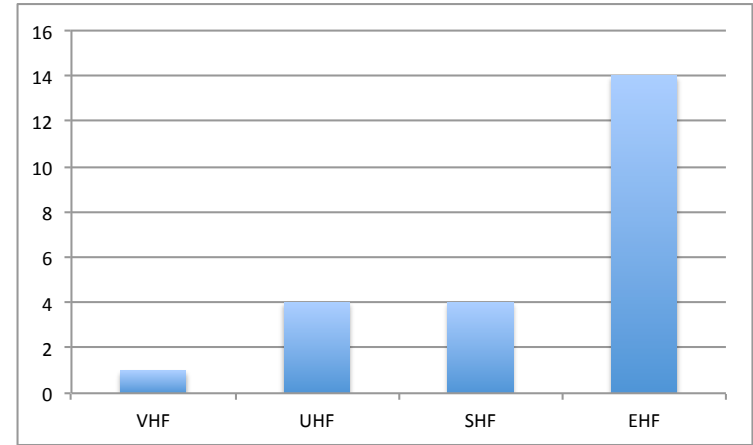
US246 No station shall be authorized to transmit in the
following bands: ... 100-102 GHz, 109.5-111.8 GHz,
114.25-116 GHz, 148.5-151.5 GHz, 164-167 GHz, 182-
185 GHz, 190-191.8 GHz, 200-209 GHz, 226-231.5 GHz,
250-252 GHz. (Allocations <100 GHz omitted)

Available Spectrum from RF to THz Bands

Size of Unavailable Bands



Number of Unavailable Bands



- These charts are based on US allocations that differ slightly from ITU RR 5.340
- ITU designates:
 - VHF: 30 – 300 MHz
 - UHF: 300 MHz – 3 GHz
 - SHF: 3 - 30 GHz
 - EHF: 30-300 GHz

Previous National Spectrum Policy Precedents



- From 2003 to 2019 highest frequency permitted for nonexperimental license in US was 95 GHz



- In 2012 UK permitted unlicensed use of the 122-123 GHz and 244-246 GHz bands up to 20 dBm EIRP



- In 2014 these limits were extended to apply to whole EU



- In 2014 Japan permitted use of 116-134 GHz but technical details not readily available

Recent National Policy/Regulatory Activity

FCC Decision 3/21/19

Spectrum Horizons NPRM Outcome

- https://docs.fcc.gov/public/attachments/FCC-19-19A1_Rcd.pdf

BAND	BANDWIDTH	POWER (AVERAGE EIRP)
116-123 GHz	7 GHz	40 dBm*
174.8-182 GHz	7.2 GHz	40 dBm*
185-190 GHz	5 GHz	40 dBm*
244-246	2 GHz	40 dBm*

Also included new rules for experimental licenses

Ofcom (UK) Proposals 1/17/20

- https://www.ofcom.org.uk/__data/assets/pdf_file/0034/189871/100-ghz-consultation.pdf

BAND	BANDWIDTH	POWER (AVERAGE EIRP)
116-122 GHz	6 GHz	Indoor 40dBm Outdoor 20 dBm
174.8-182 GHz	7.2 GHz	Indoor 40dBm Outdoor 20 dBm
185-190 GHz	5 GHz	Indoor 40dBm Outdoor 40 dBm

Recent International Developments

- WRC 2019 concluded in November in Sharm El-Sheikh, Egypt
- Before WRC 2019 there were not allocations above 275 GHz
- Allocations made for fixed and mobile for: 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz
- Resolution made for a study plan for ITU-R for increased sharing above 71 GHz. Bands of interest include 100 - 102 GHz, 116 - 122.25 GHz, 148.5 - 151.5 GHz, 174.8 - 191.8 GHz, 226 - 231.5 GHz and 235 - 238 GHz

Need More Work on Sharing

- Protecting Radio Astronomy is more straightforward
- Protecting Earth Observation is more complicated
- There is 900 GHz of room to work it out!
- Many issues deal with comms, but may not be applicable to radar and sensing
- Channels with 10s of GHz of bandwidth would be great
- I need more sensors for my car so it doesn't run over Sailor!

The End

- I hope my story kept you awake at the end of day
- mmWave/THz can contribute to the RadSenseComm of Things on the Internet/Internet of Things
- The regulatory framework for spectrum above 100 GHz is beginning to take shape