

# Impact of Electric Vehicle on AM Radio Reception

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IEEE EMCS Life Senior Member



# Outline

## Introduction

## Basic Concepts relative to in-vehicle AM radio reception and EMI

- Characteristics of electrically short antennas
- EMI source coupling mechanisms

## Electric Powertrain Design & Characteristics

- Internal coupling mechanisms

## Mitigation options

## Customer Experience: Perception vs Reality

# Introduction



Source: Autoline Network



*The assault on AM radio is short-sighted and must be reversed.*

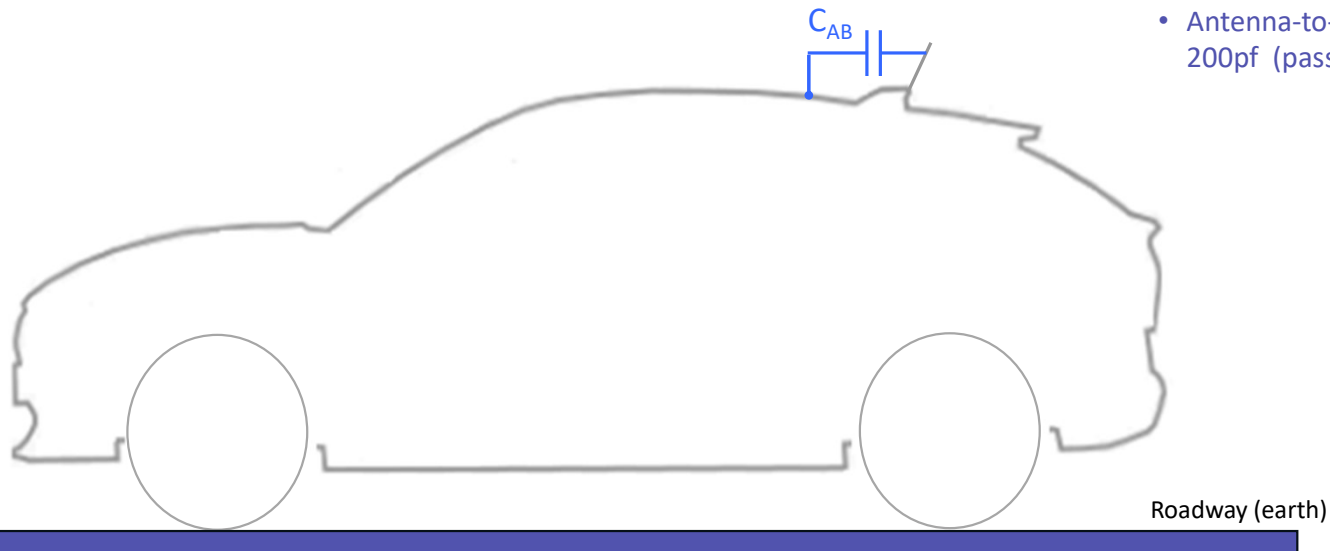
Source: Steve Forbes

# Basic Physical Concepts

The vehicle AM antenna is electrically short

$C_{AB}$ : Receiving antenna system capacitance

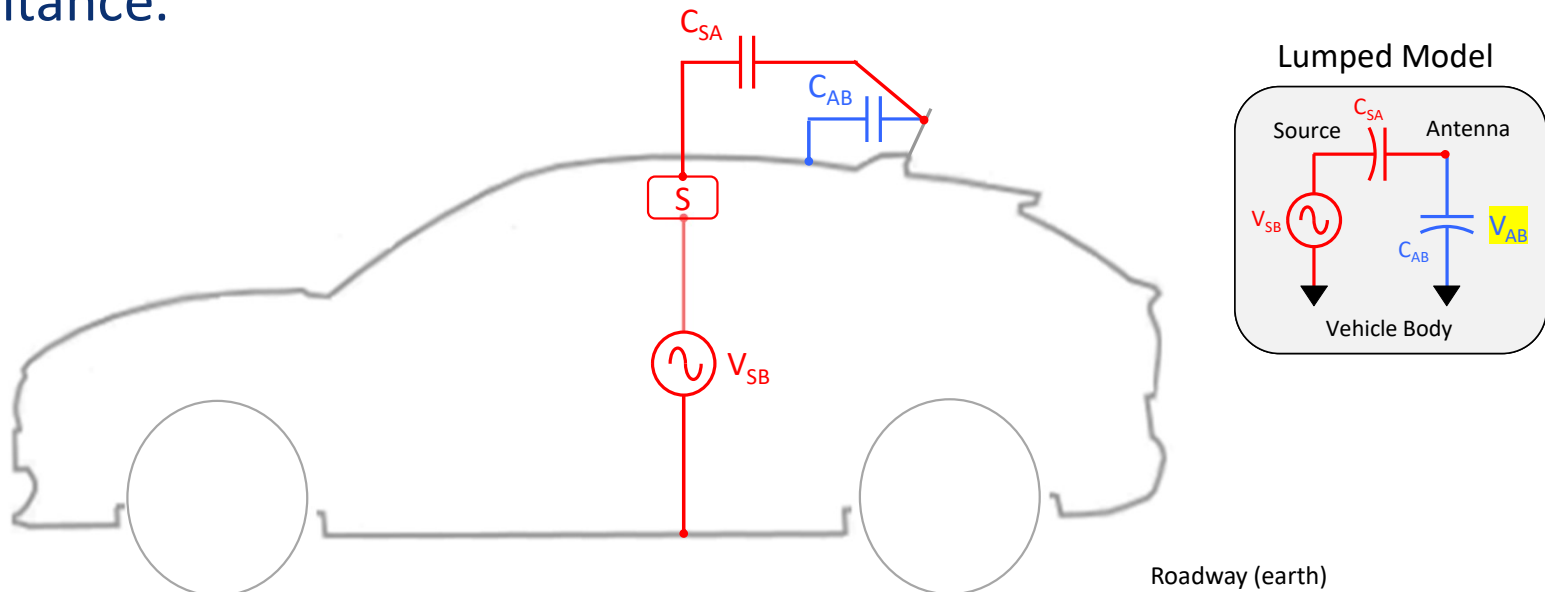
- Antenna element capacitance  $\sim 10$  pF
- Antenna-to-radio cable capacitance  $\sim 200$  pf (passive antennas)



$C_{AB}$ :  $\sim 10 - 200$  pf

# Basic Physical Concepts

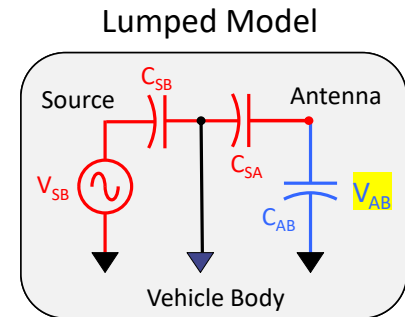
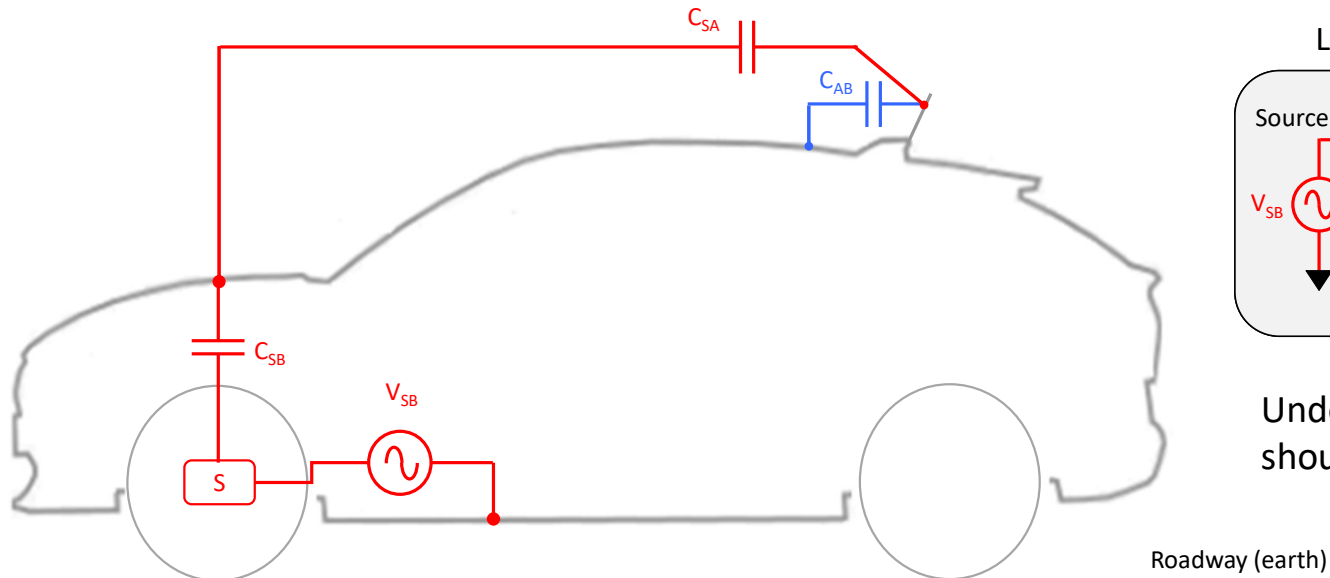
Classic AM Coupling Model: EMI coupling is “voltage driven” via mutual capacitance.



$C_{AB}$ : ~ 10 – 200 pf    **S**: Noise Emitting Structure     $V_{SB}$ : Noise potential between structure and vehicle body     $C_{SA}$ : ~ 2 - 5 pf  
 $V_{AB}$ : induced antenna noise potential

# Basic Physical Concepts

## What about under hood Packaging?

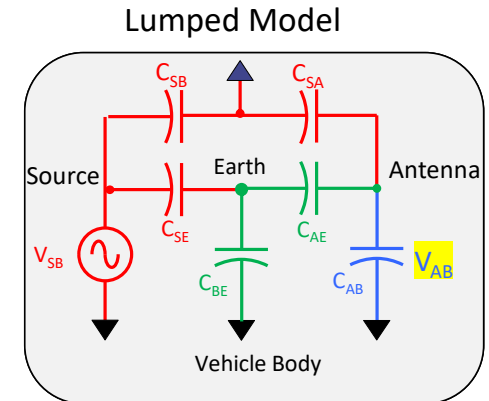
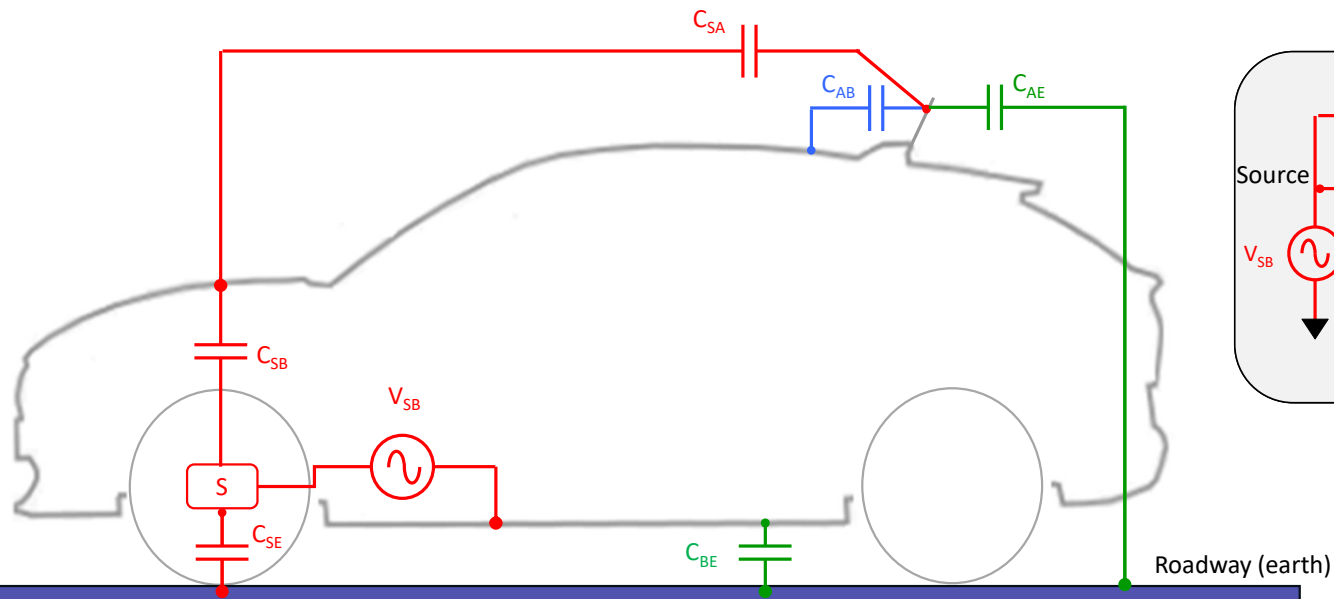


Under hood packaging should minimize coupling!

$C_{AB}$ : ~ 10 – 200 pf     $S$ : Noise Emitting Structure     $V_{SB}$ : Noise potential between structure and vehicle body     $C_{SA}$ : ~ 2 - 5 pf  
 $V_{AB}$ : induced antenna noise potential     $C_{SB}$ : ~ 2-5 pf

# Basic Physical Concepts

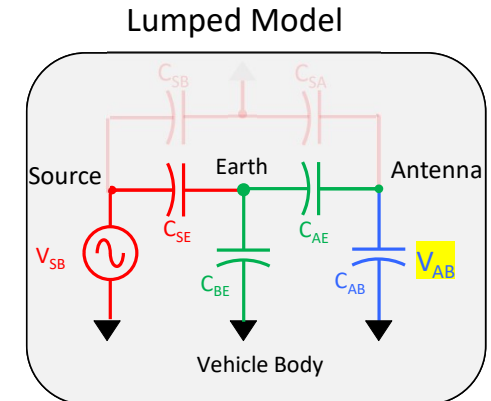
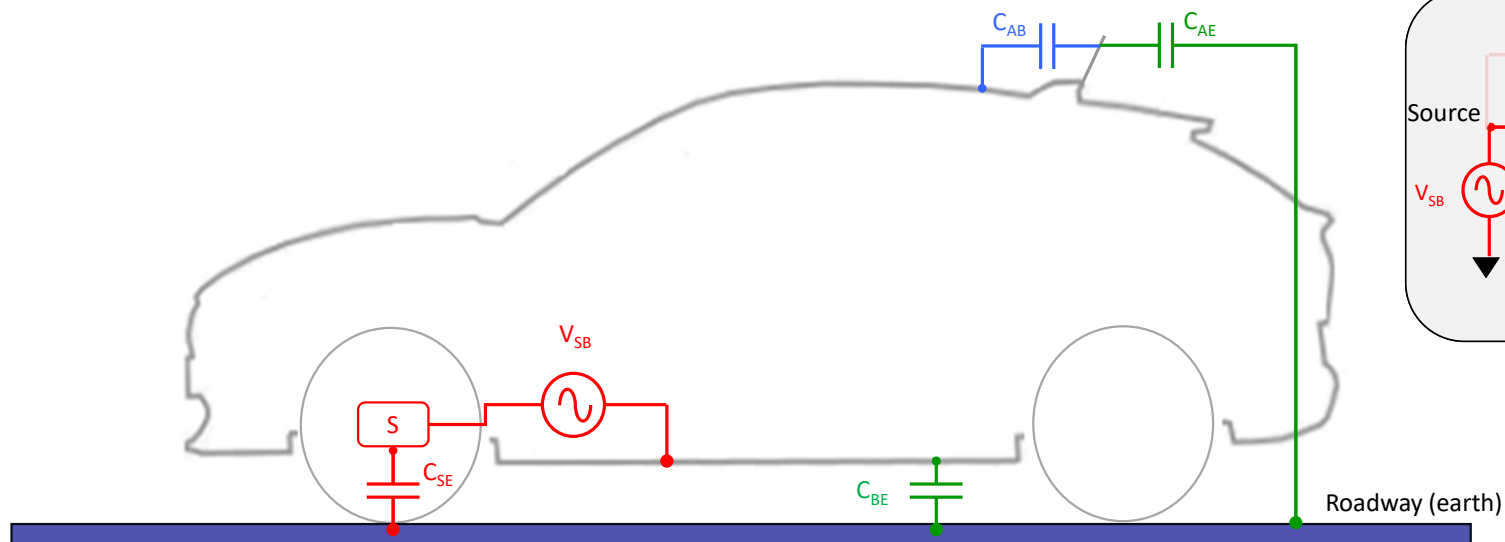
Parasitic capacitance to roadway must be considered



$C_{AB}$ :  $\sim 10 - 200$  pf     $S$ : Noise Emitting Structure     $V_{SB}$ : Noise potential between structure and vehicle body     $C_{SA}$ :  $\sim 2 - 5$  pf  
 $V_{AB}$ : induced antenna noise potential     $C_{SB}$ :  $\sim 2-5$  pf     $C_{SE}$ :  $\sim 200$  pf     $C_{BE}$ :  $\sim 1$ nF     $C_{AE}$ :  $< 1$ pf

# Basic Physical Concepts

## “4-Capacitor” AM Coupling Model



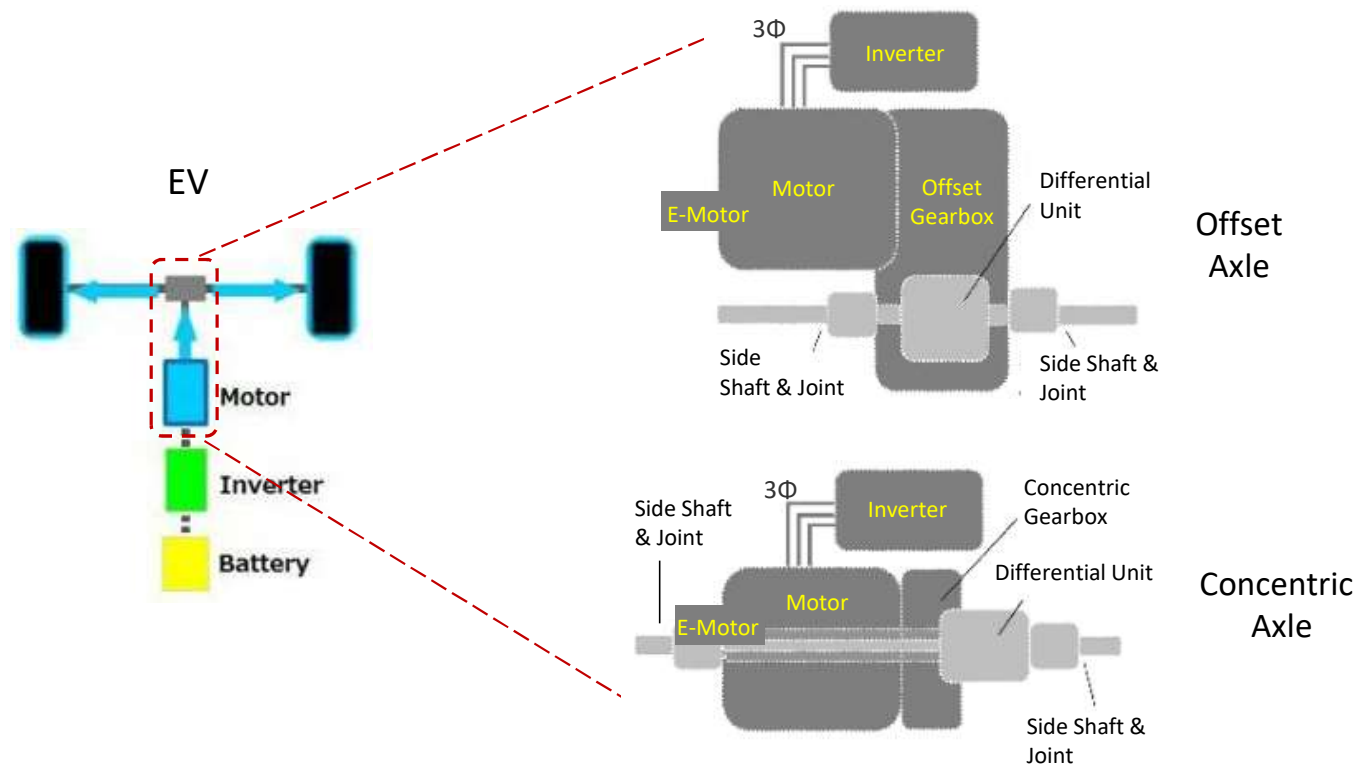
$C_{AB}$ :  $\sim 10 - 200$  pf    **S**: Noise Emitting Structure     $V_{SB}$ : Noise potential between structure and vehicle body

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# Basic Physical Concepts

## EV Concentric vs Offset Transaxle Design



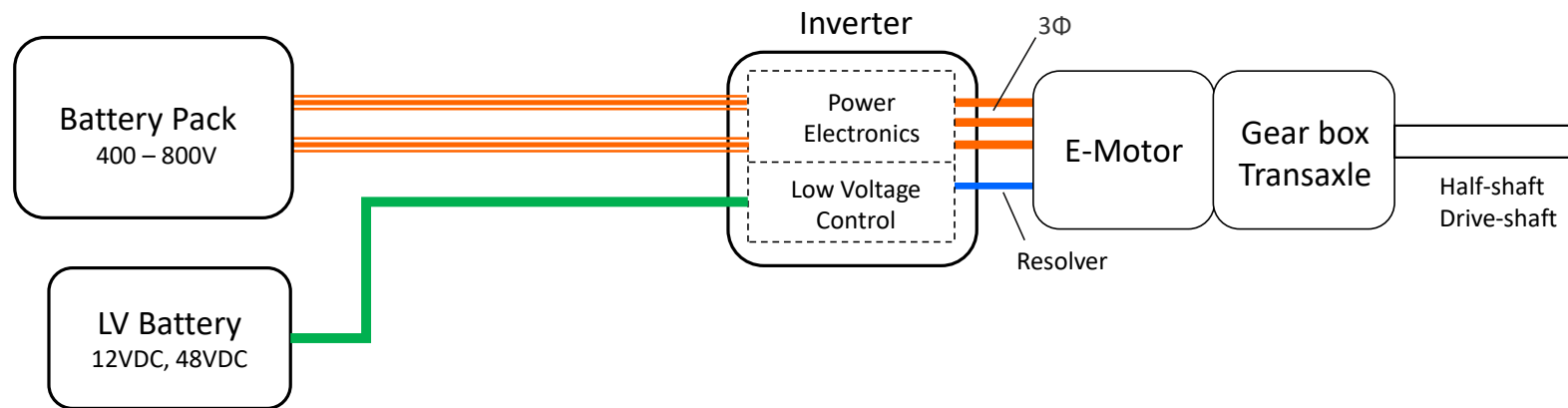
# Basic Physical Concepts

## Various electric motors types used for EV applications

- DC Brush Motor (no longer used)
- Brushless DC Motors (common in many EVs)
- Permanent Magnet Synchronous Motor
- Three Phase AC Induction Motors (High performance, used in Tesla Model S, Toyota RAV 4 EV)
- Switched Reluctance Motors.
- Synchronous Reluctance Motors
- Axial Flux Ironless Motors

# Basic Physical Concepts

## Basic EV Propulsion Architecture



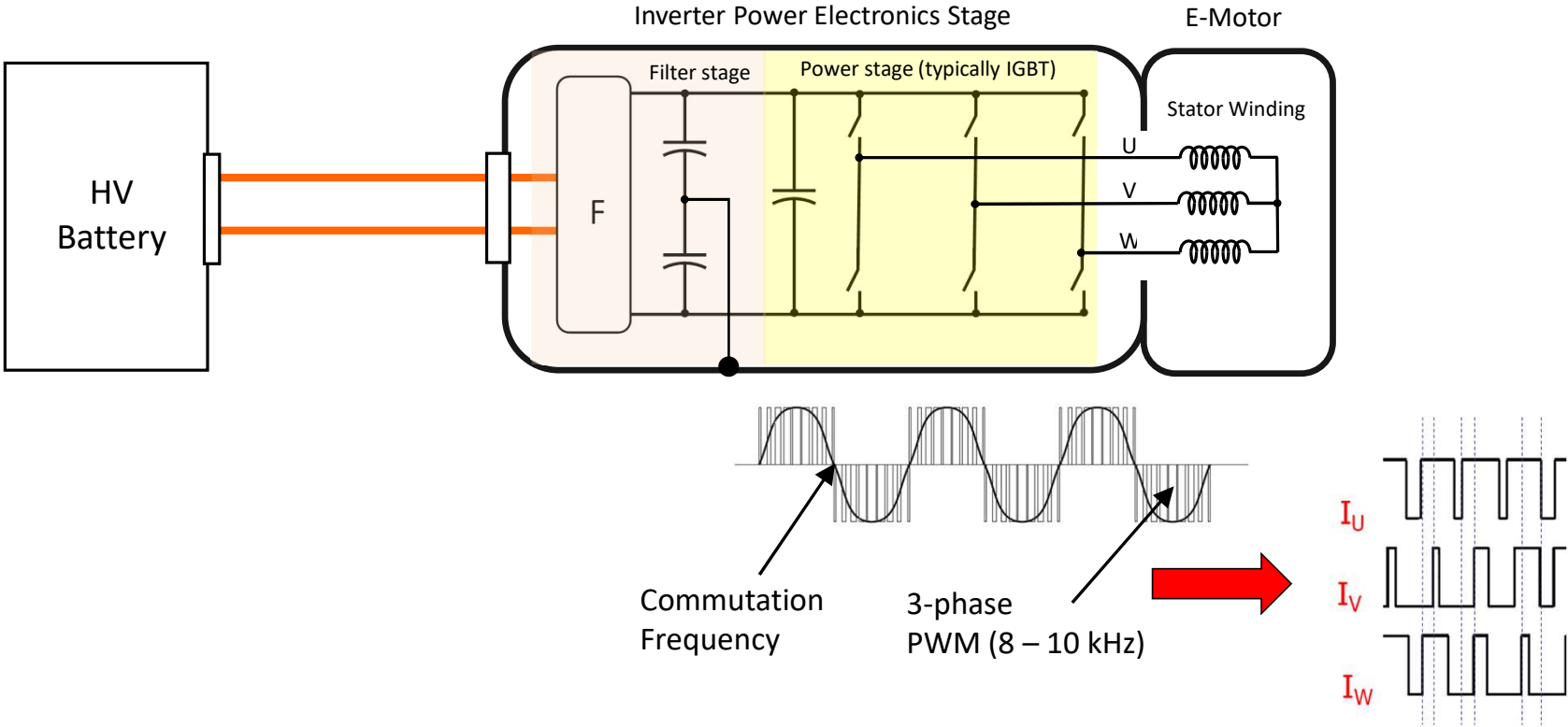
# Coupling Paths to Vehicle Antenna

There are multiple coupling paths with respect to radiation from the vehicle.

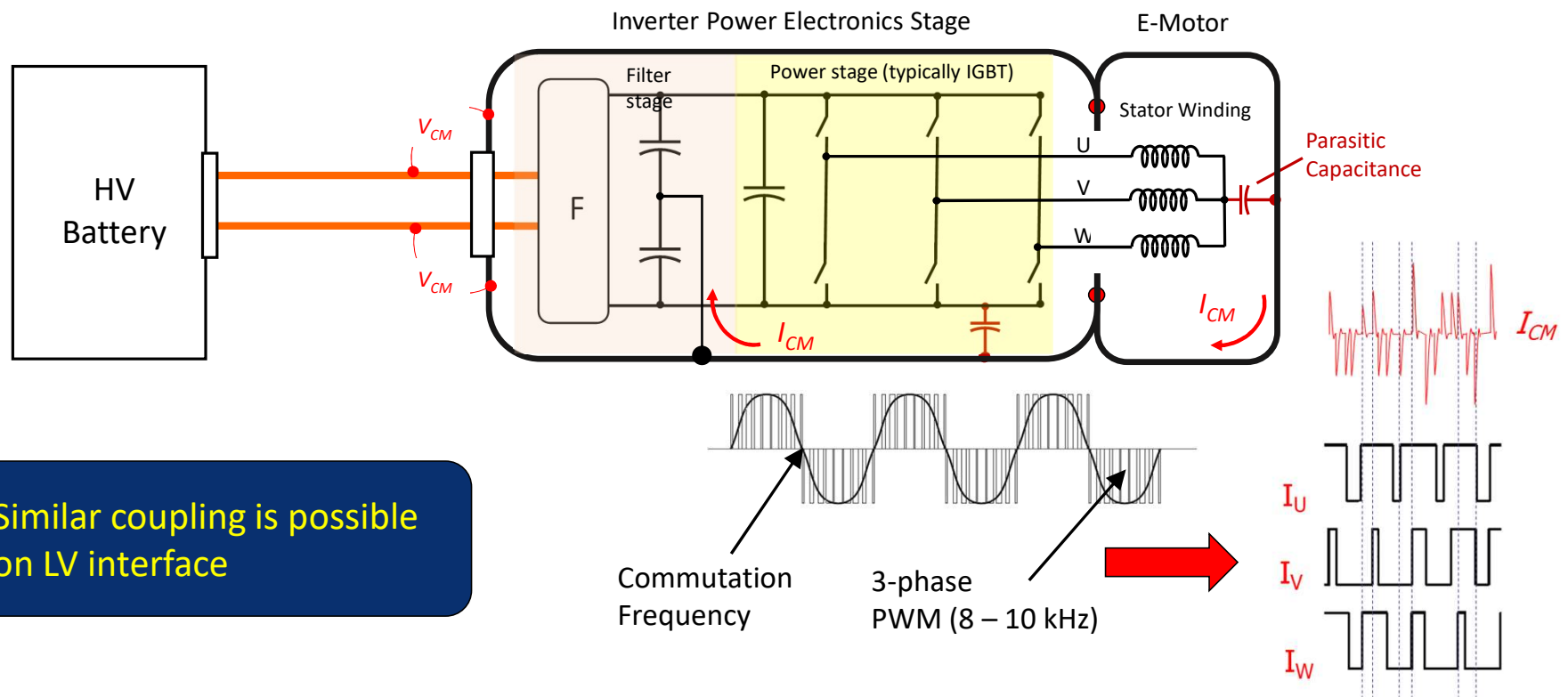
- Inverter induced noise on HVDC bus
- Inverter induced noise on LV wiring (LV power, CAN, Resolver etc)
- Inverter induced noise on E-Motor Transaxle half-shafts

**Dominate coupling path to vehicle antenna is via 4-capacitor model!**

# Source Characteristics

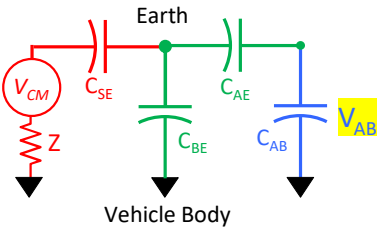
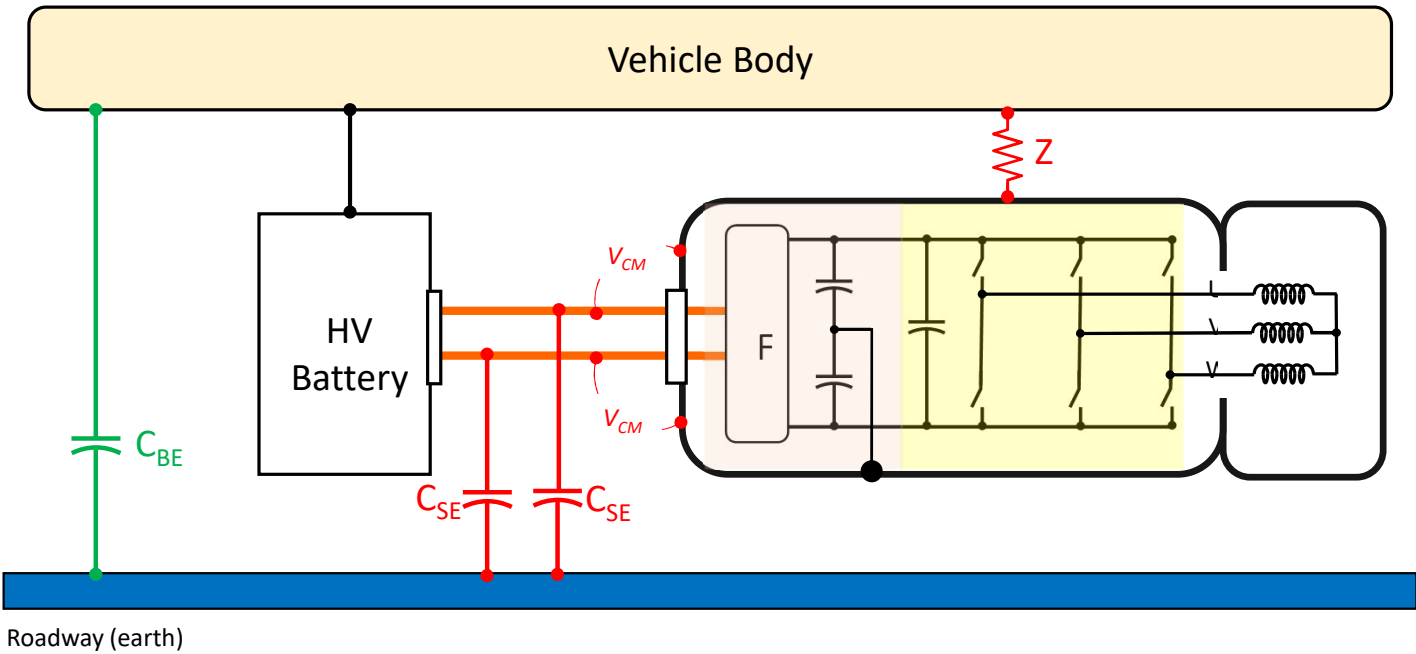


# Inverter Noise Coupling to HV Power Bus

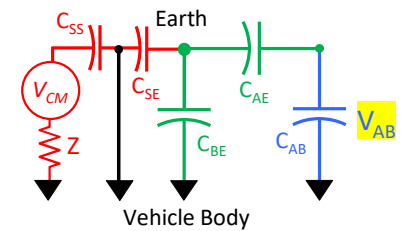
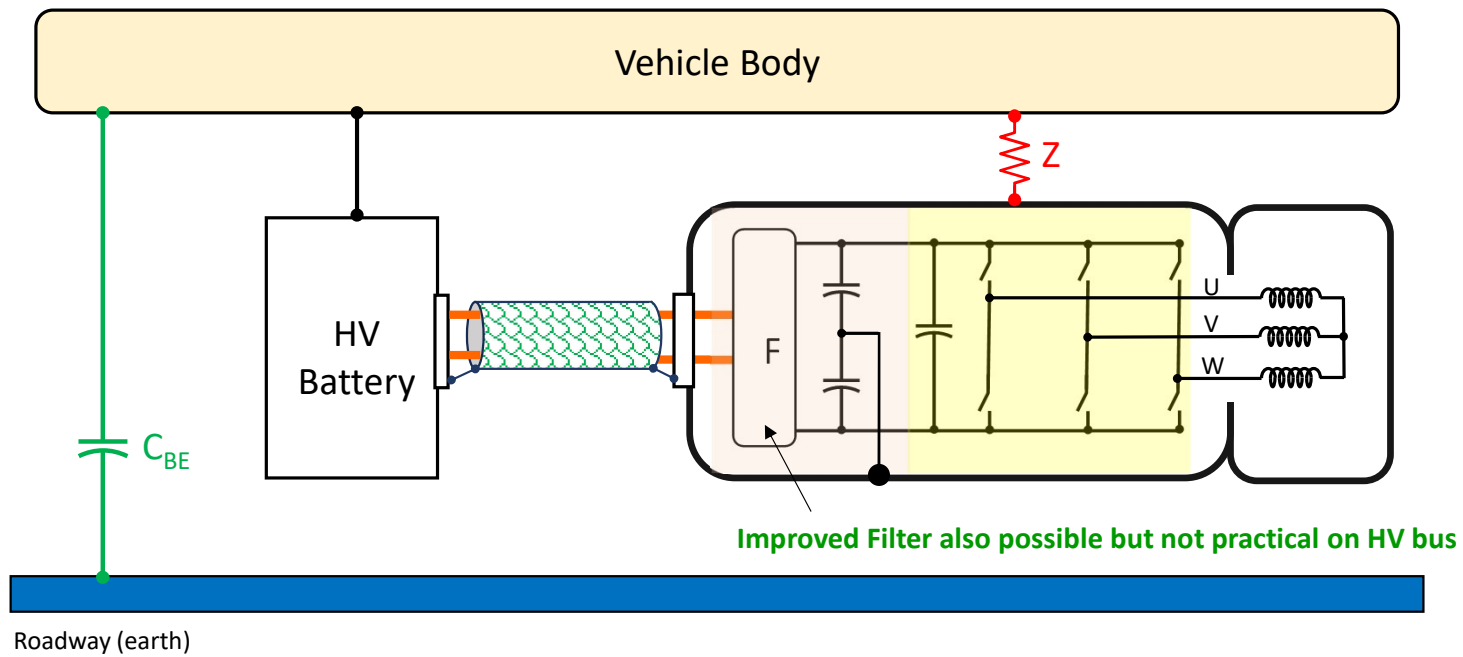


Similar coupling is possible on LV interface

# Coupling to Earth and Vehicle Antenna



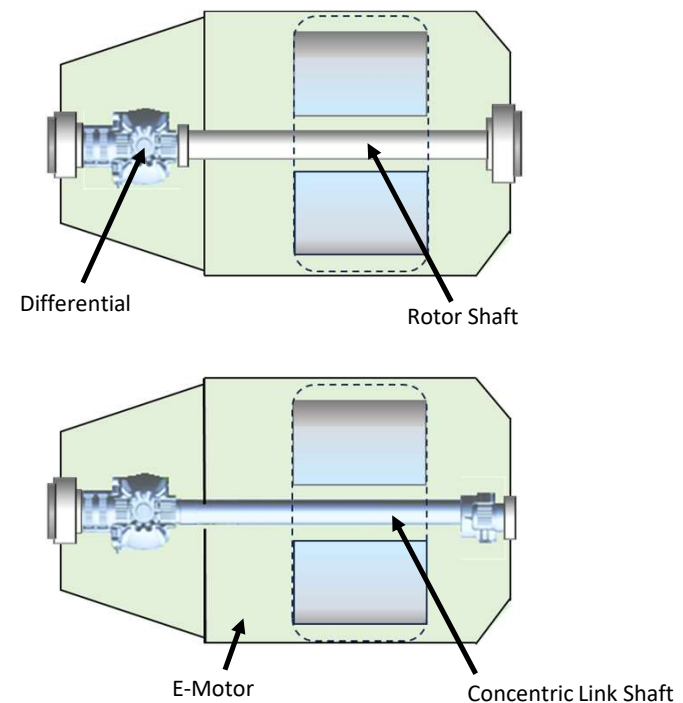
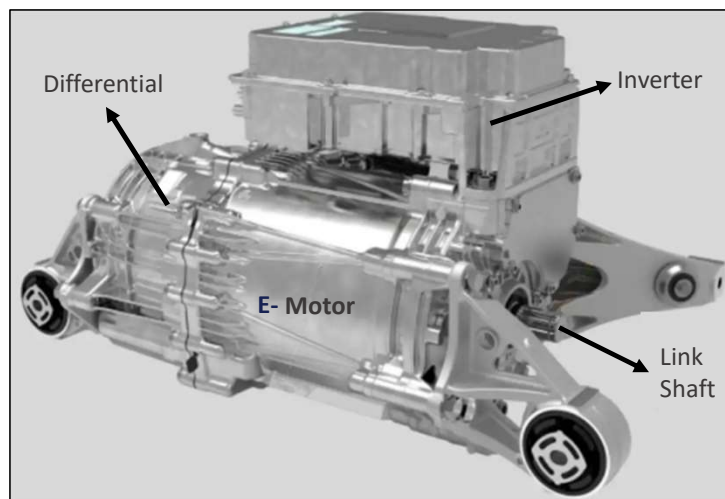
# Mitigation Options



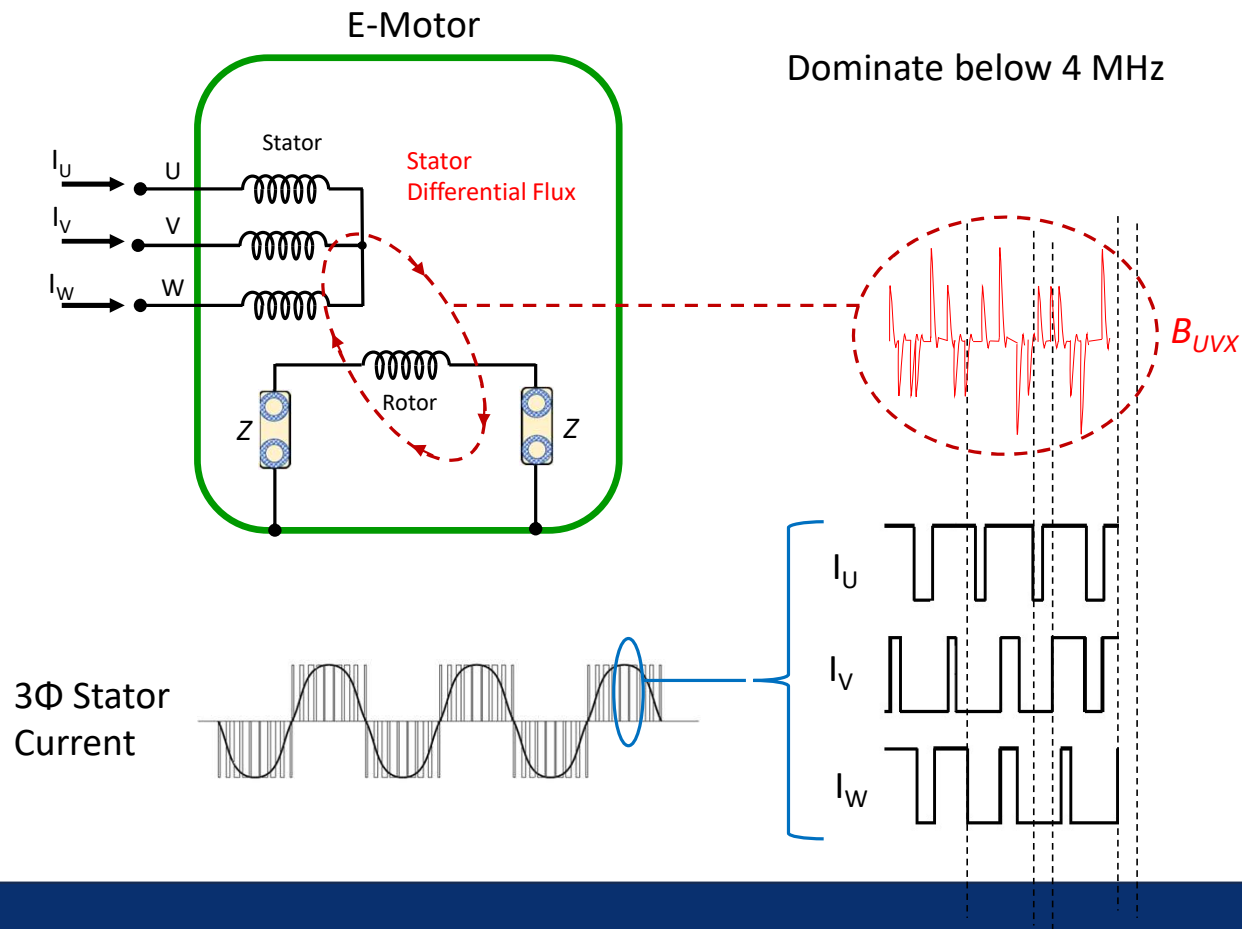


# Inverter Noise Coupling between Stator and Rotor

## Concentric Axle Power Drive Unit

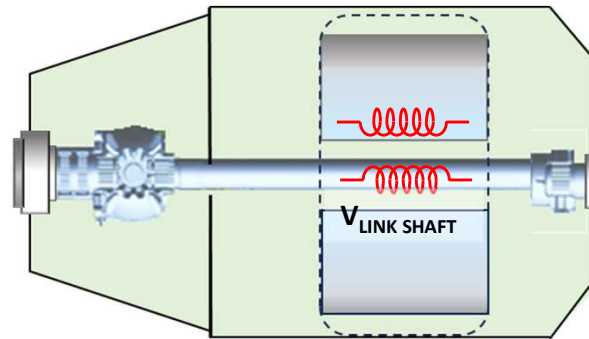
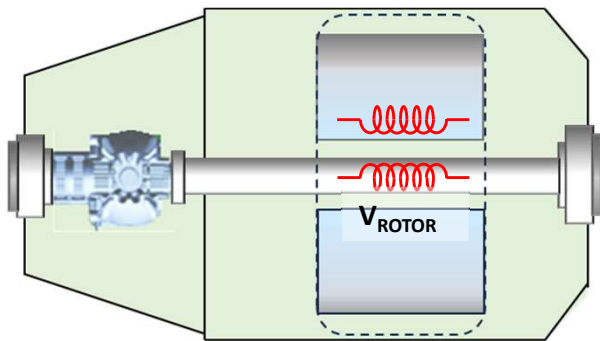


# Noise Coupling between Stator and Rotor

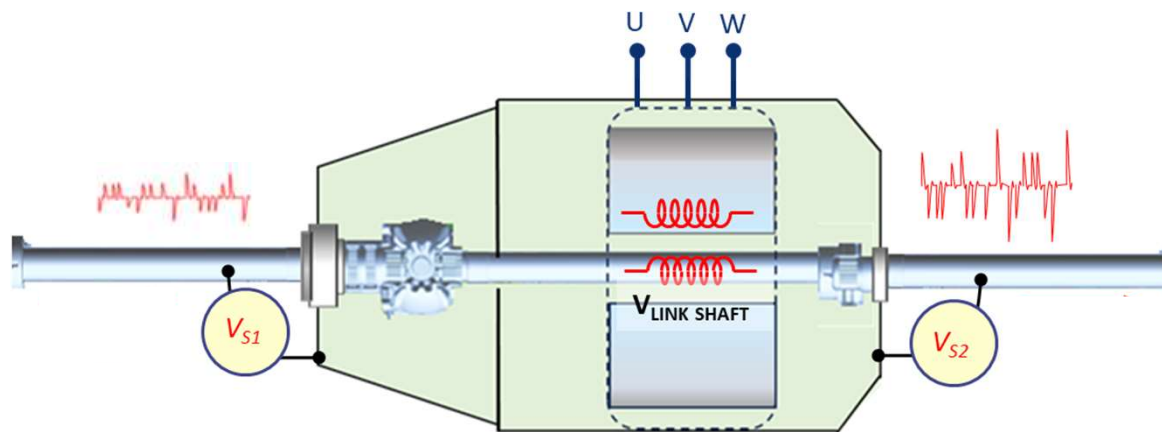


# Noise Coupling Between Stator and Rotor

Stator differential flux produces longitudinal voltage on rotor and link shaft

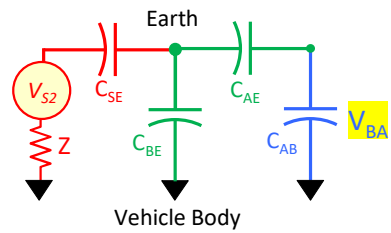
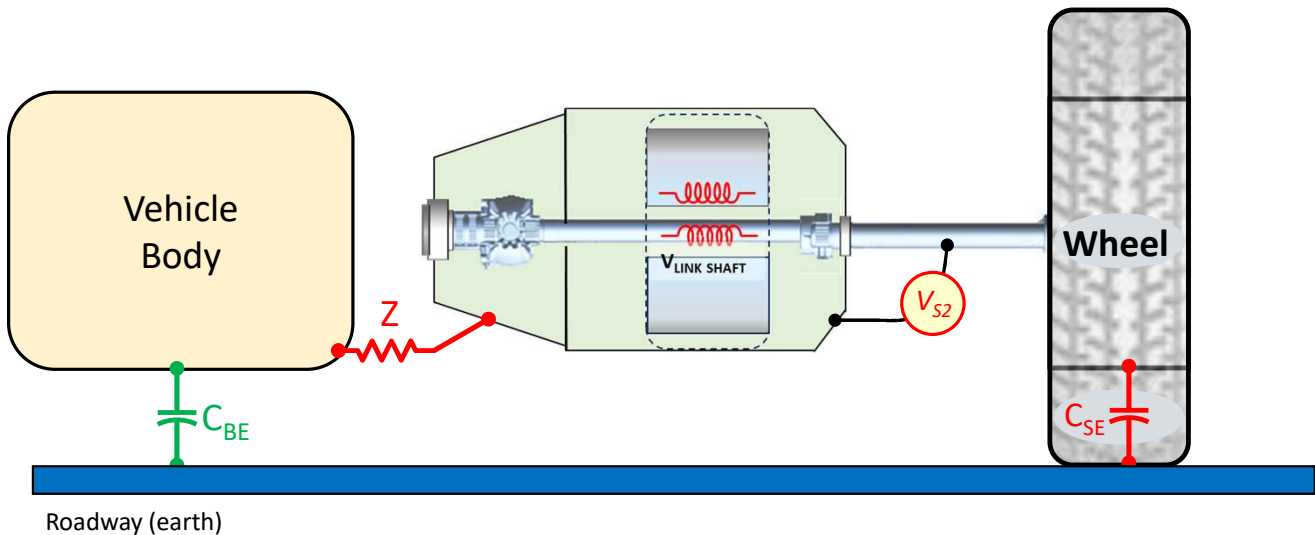


# Noise Coupling to Half Shafts



$$V_{S2} \gg V_{S1}$$

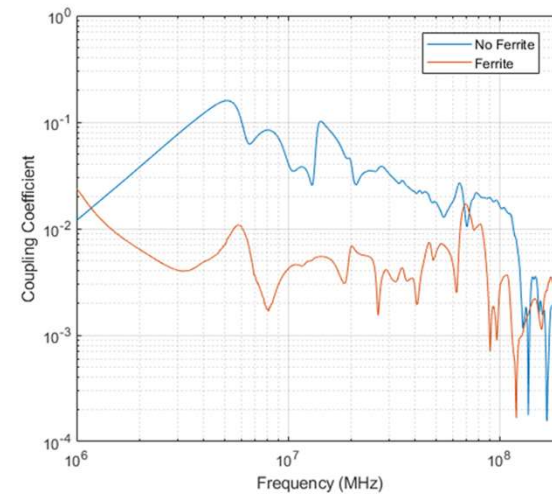
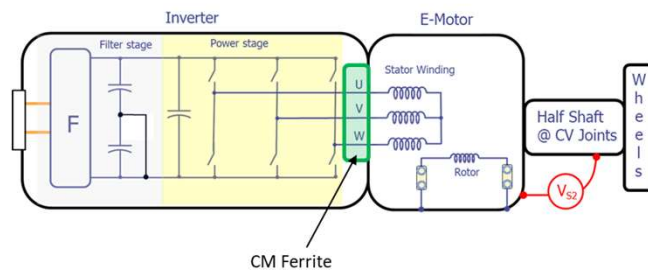
# Coupling to Earth and Vehicle Antenna



# Mitigation Options

## Reduce flux coupling via change to stator winding design Reduce inverter conducted noise

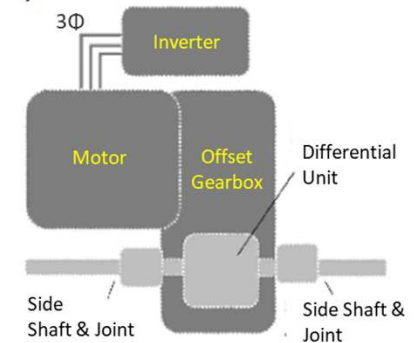
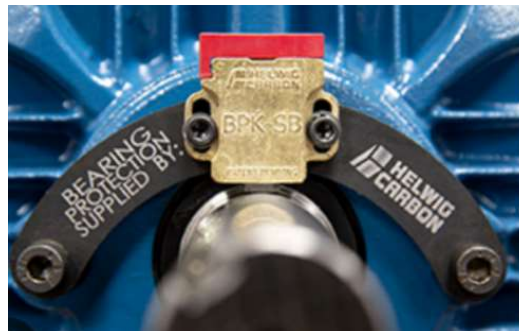
- Reduce switching frequency (N & V issues and increased X-capacitance)
- Reduce PWM slew rate (decreased efficiency thus impacting vehicle range)
- Filtering at 3 $\Phi$  interface (\$\$\$, bulky, can impact efficiency thus impact range)



# Mitigation Options

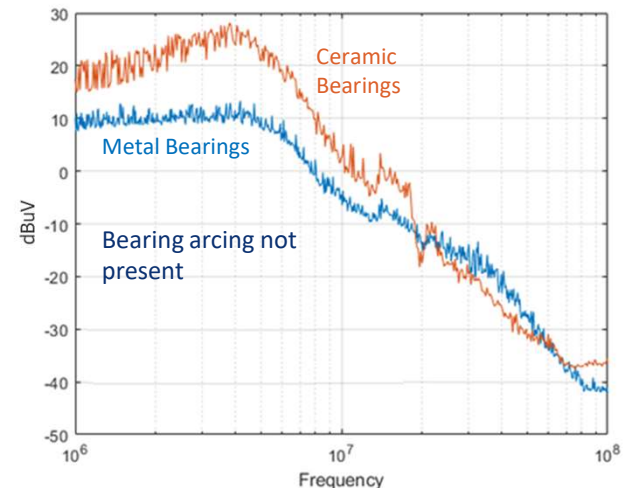
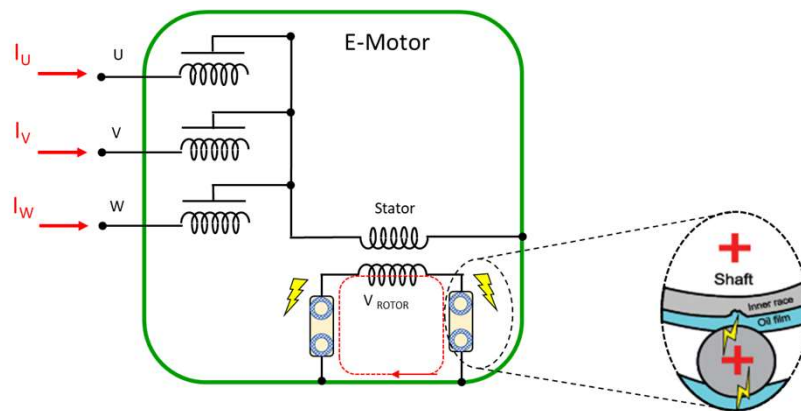
## Reduce noise voltage on Half shafts

- Replace concentric with offset axle design(packaging and cost challenges)
- Use non-conductive link shaft and/or half shaft (\$\$\$\$ , not practical)
- Ground Link or half shaft to motor housing
  - Commonly used on VFD motors to reduce bearing wear.
  - Exists on some vehicles (e.g. Nissan Leaf)
  - Potential maintenance issues
  - High cost



# Regulatory Conflicts

- Above 20 MHz, RF emissions can be affected by bearing arcing, which occurs from the induced shaft voltage.
- Mitigation approach is to use ceramic bearings. While effective above 20 MHz, it results in increased shaft voltage magnitude in AM band.



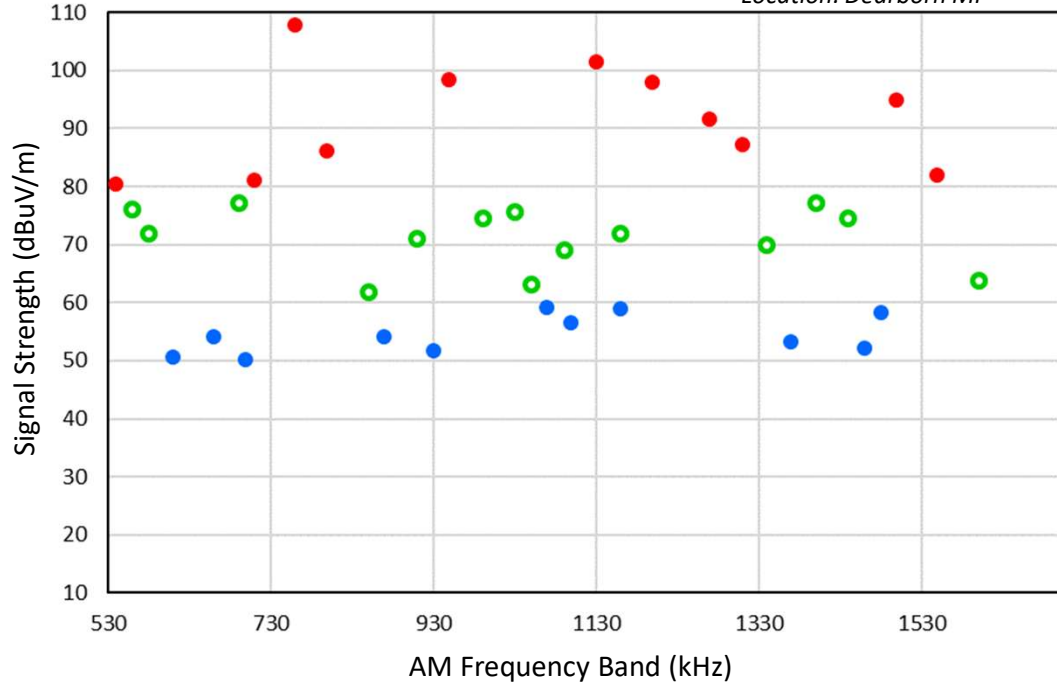


# Customer Impact ?

## AM reception attribute is subjective

- Strong-Very Strong AM Stations
- Medium AM Stations
- Weak AM Stations

Source: zipsignal.v-soft.com  
Location: Dearborn MI

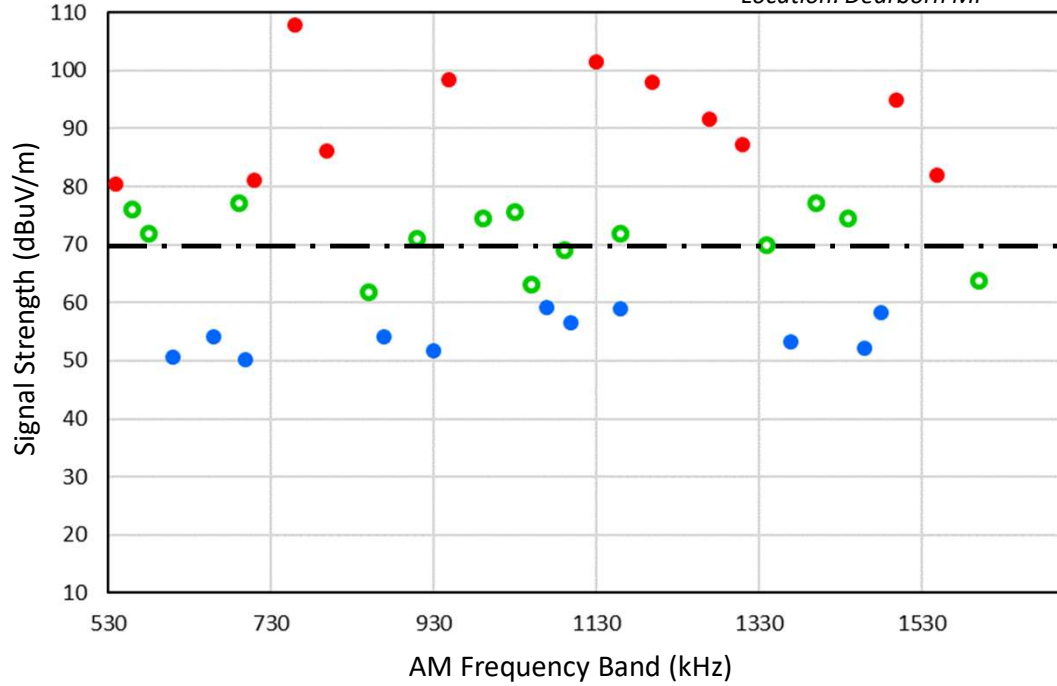


# Customer Impact ?

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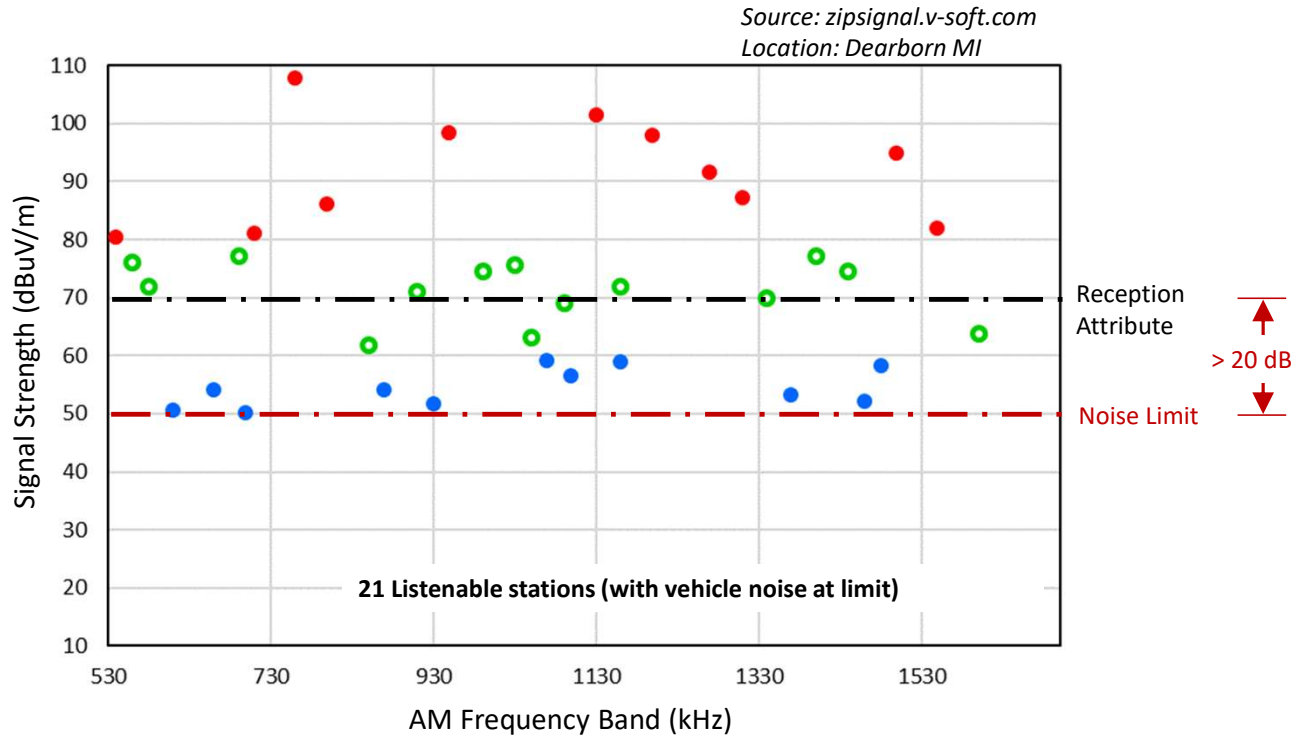


Reception Attribute  
Similar with many OEMs

# Customer Impact ?

## Objective limits

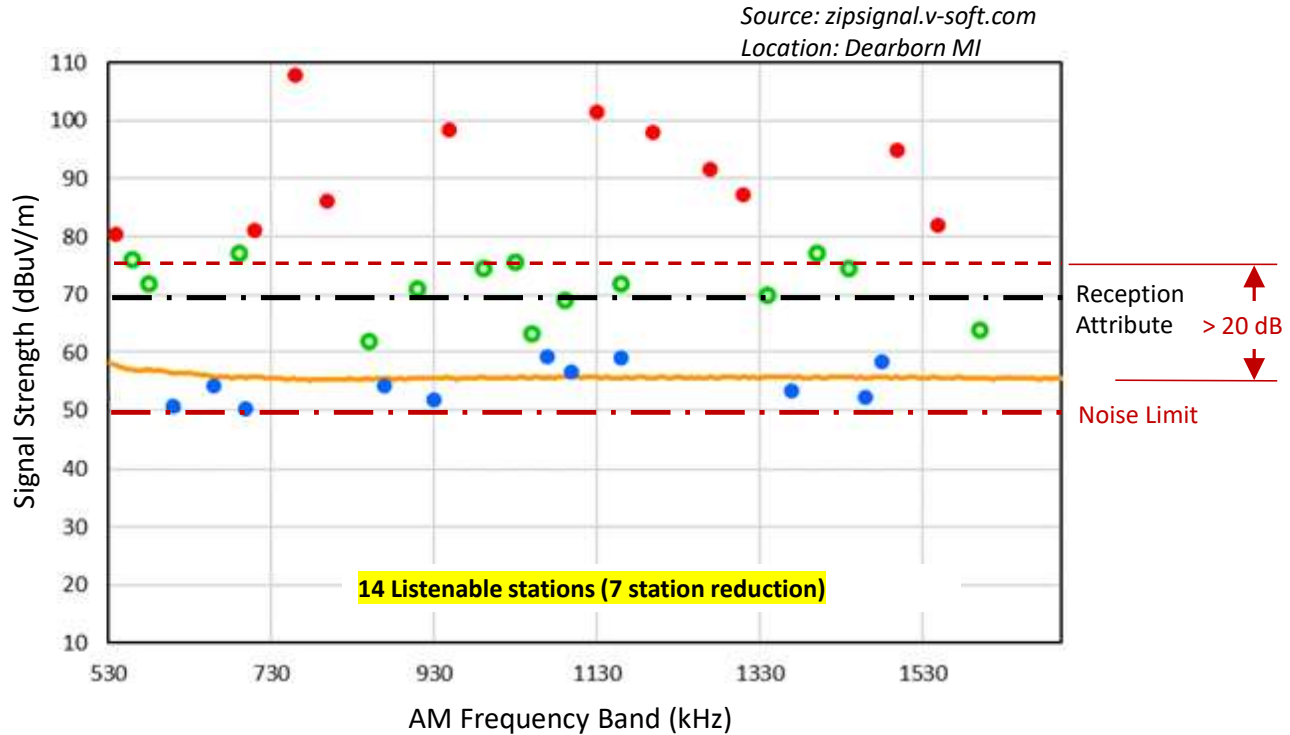
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# Customer Impact ?

## EV vehicle noise impact

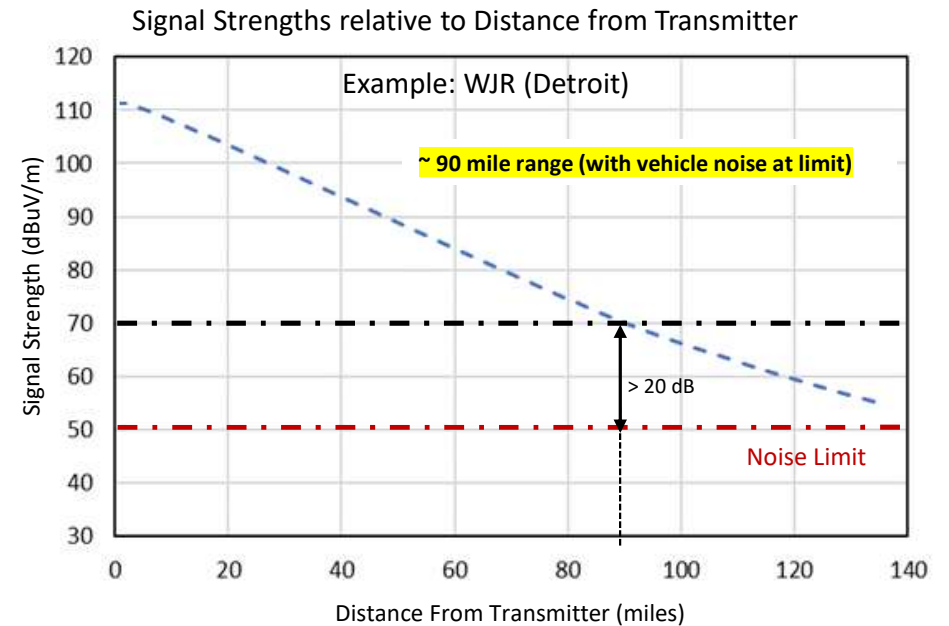
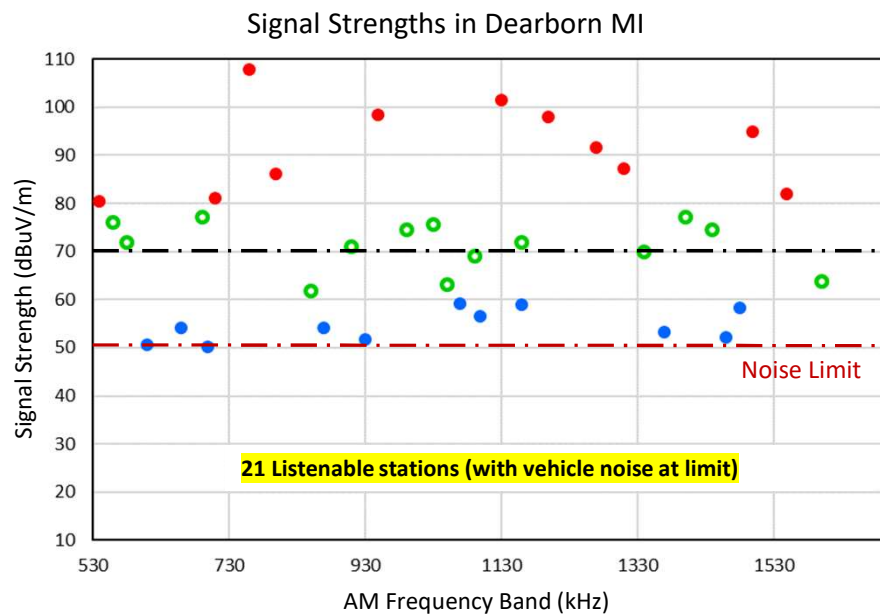
- Strong-Very Strong AM Stations
- Medium AM Stations
- Weak AM Stations



# Customer Impact ?

## Typical ICE AM reception range

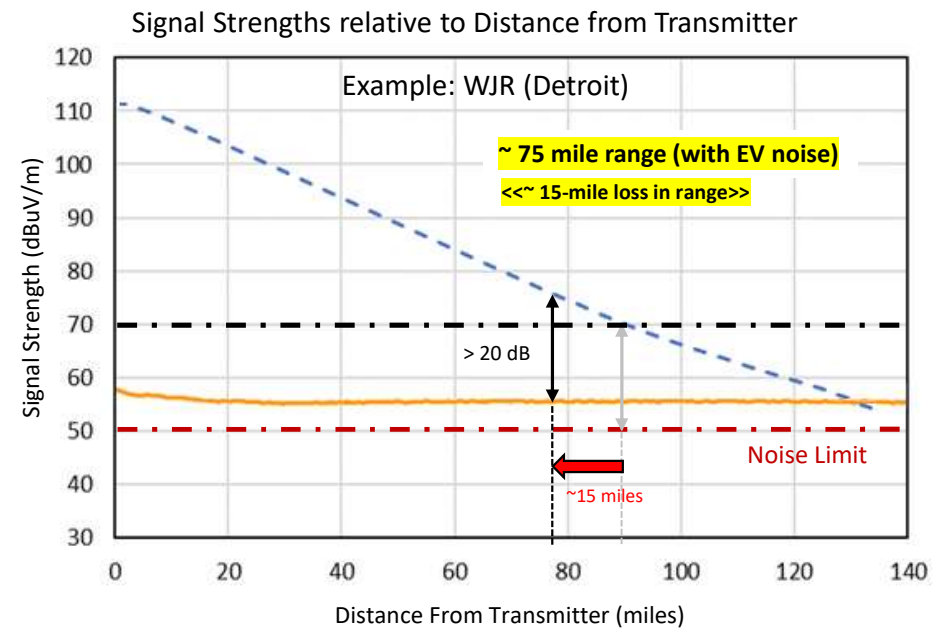
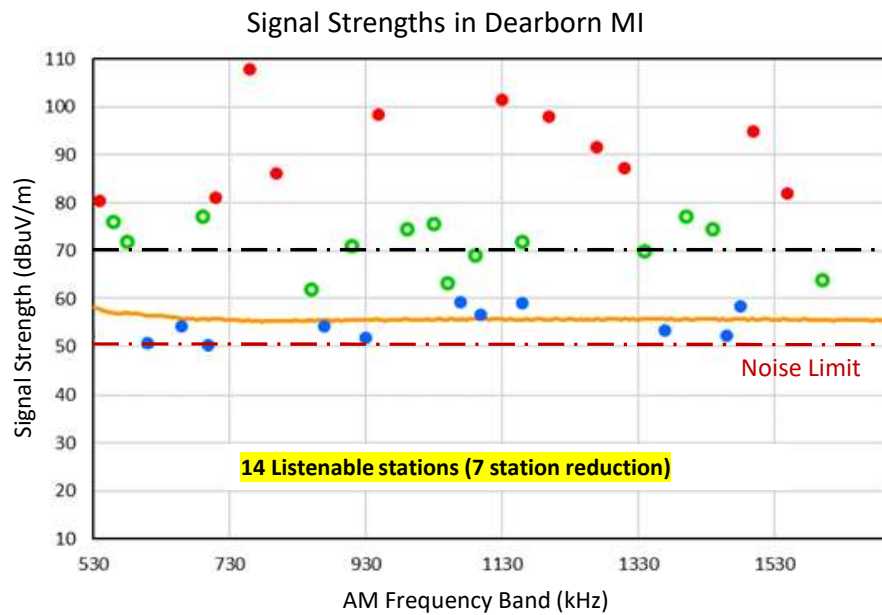
Source: zipsignal.v-soft.com  
Location: Dearborn MI



# Customer Impact ?

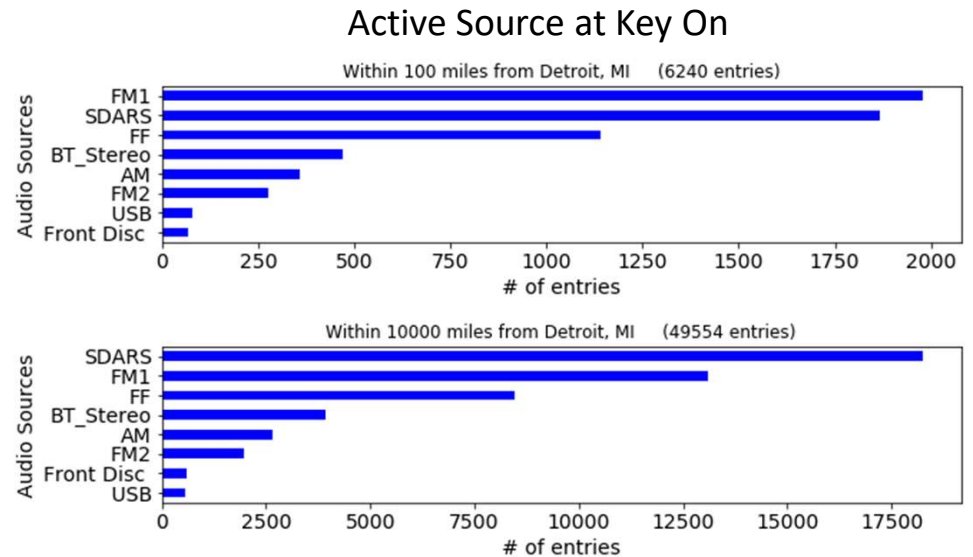
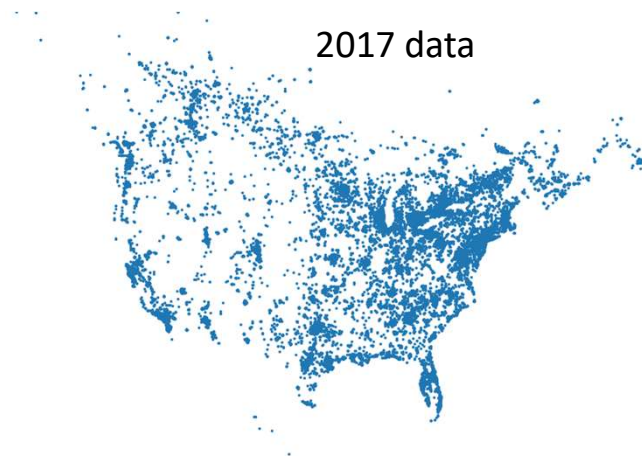
## EV Impact on AM reception range

Source: zipsignal.v-soft.com  
Location: Dearborn MI



# Perception vs Reality

OEM vehicle data analytics tells a different story!



2023 data: AM average listening time: 3.3 min

# Perception vs Reality

Published research shows that over the air AM/FM radio is the dominate community medium including young listeners

- “AM radio reached 82.3 million Americans monthly representing on 1 of 3 US AM/FM radio listeners” (source: Nielsen)
- “57% are tuned to news/talk formatted stations” (source: Westwood One)

AM/FM listenership is being impacted by streaming and podcasts (source: Edison Research)

	Share of ad-supported audio among persons 25-54	
	Q4 2017	Q1 2022
Over-the-air AM/FM radio	73%	61%
Podcasts	6%	13%
AM/FM radio streaming	6%	11%
Ad-supported Pandora	10%	8%
Ad-supported SiriusXM	2%	4%
Ad-supported Spotify	3%	3%

Broadcast radio listenership is declining!

Source: Edison Research, "Share of Ear," Q4 2017 vs. Q1 2022.

Westwood One  
AUDIO ACTIVE  
GROUP



# Perception vs Reality

It's reported that AM radio is critical to Emergency Alert System (EAS)

*“AM radio stations have a long reach, covering a much larger geographical area than a cell phone tower, and can be accessed by anyone with a simple radio device. This ensures that vital information is accessible to everyone, including those in rural or remote areas”*

*“AM radio stations continue to function during power outages, natural disasters or other emergencies, providing critical updates and information to the public. Wireless Emergency Alerts may not be as reliable in these situations, as cell towers can be damaged or overwhelmed by high call volume.”*

*Source: National Association of Broadcasters*

# Impact on EAS

## AM radio is not the sole source for emergency alerts!

*Emergency Alert System participants –radio and television broadcasters, cable systems, satellite radio and television providers, and wireline video providers – deliver state and local alerts on a voluntary basis, but they are required to deliver Presidential alerts, which enable the President to address the public during a national emergency.*

*Source: FCC.gov*

There are 77 AM stations (mostly AM) that serve as Primary Entry Points (PEP) for emergency alerts.

- PEP stations are monitored by other non-PEP stations (AM, FM, broadcast/cable TV) to cascade the emergency alert.
- In addition to the PEP stations, satellite (SXM) and internet are also monitored.

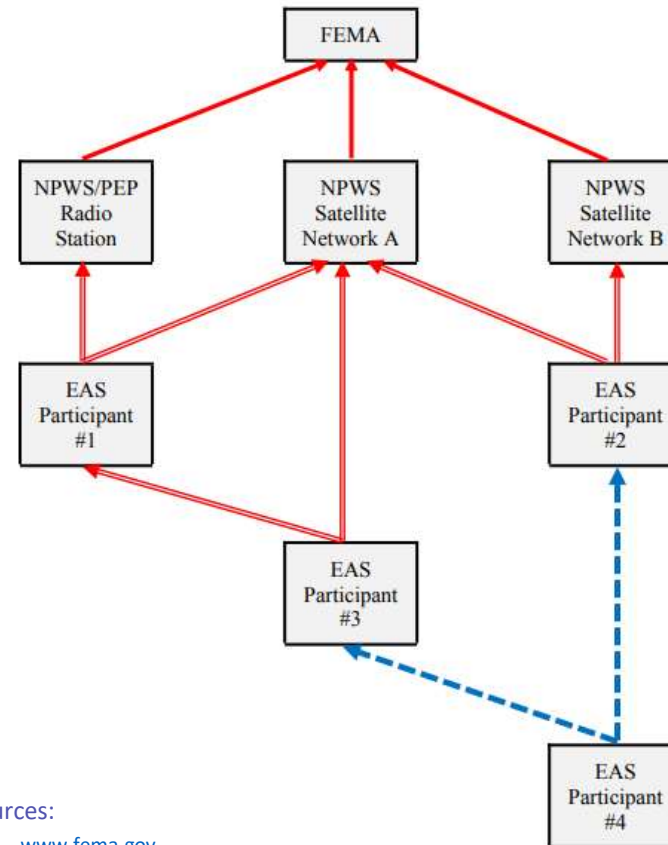
*Source: Wikipedia*

*National Association of Broadcasters*

# EAS Review

The National Public Warning System (NPWS), also known as Primary Entry Point (PEP) stations, are radio broadcast stations (AM and FM) that work with FEMA to provide emergency alert and warning information to the public before, during and after incidents and disasters.

- The NPWS can directly reach more than 90% of the U.S. population and ensures that under all conditions the President can alert and warn the public.
- Emergency alerts are redundant in they are sent via PEP satellite communications. The internet is also used.
- EAS participants include state “Primary Stations” (EAS Participant #1) and other local participants (#3, #4) in many cases having redundancy in receipt of the emergency alert.
  - Nationally, there are 4725 AM stations and 6624 FM stations. <sup>(2)</sup>



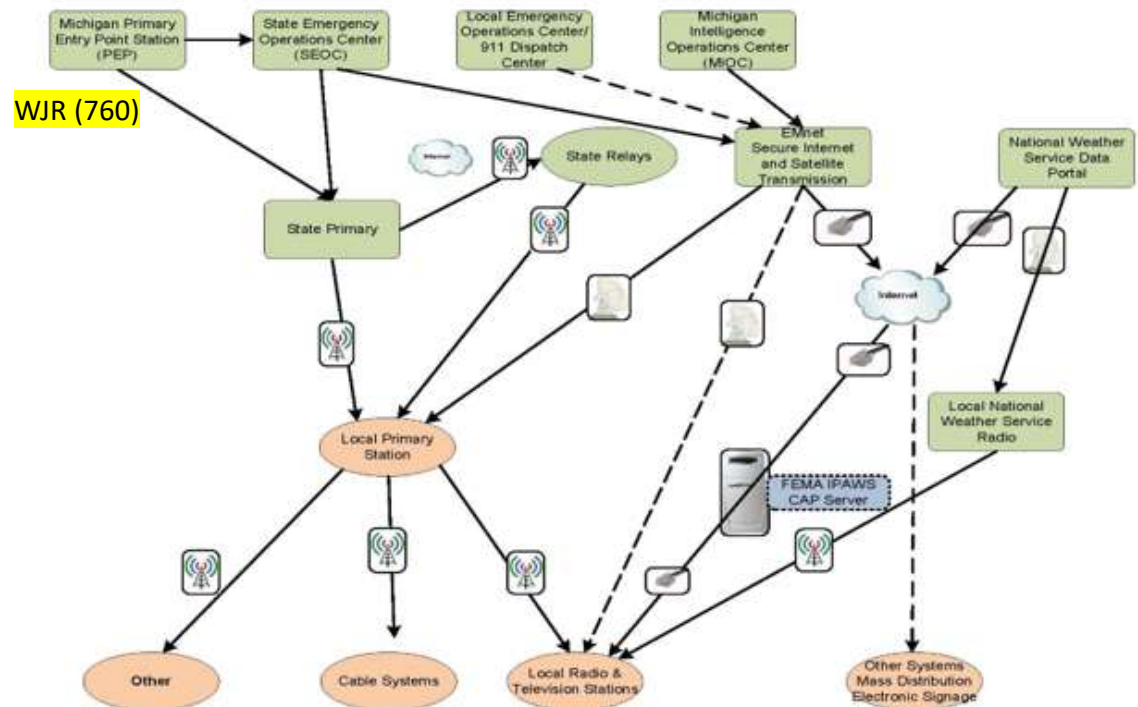
Sources:

- 1) [www.fema.gov](http://www.fema.gov)
- 2) [www.fcc.gov](http://www.fcc.gov)

## EAS topology used in the State of Michigan

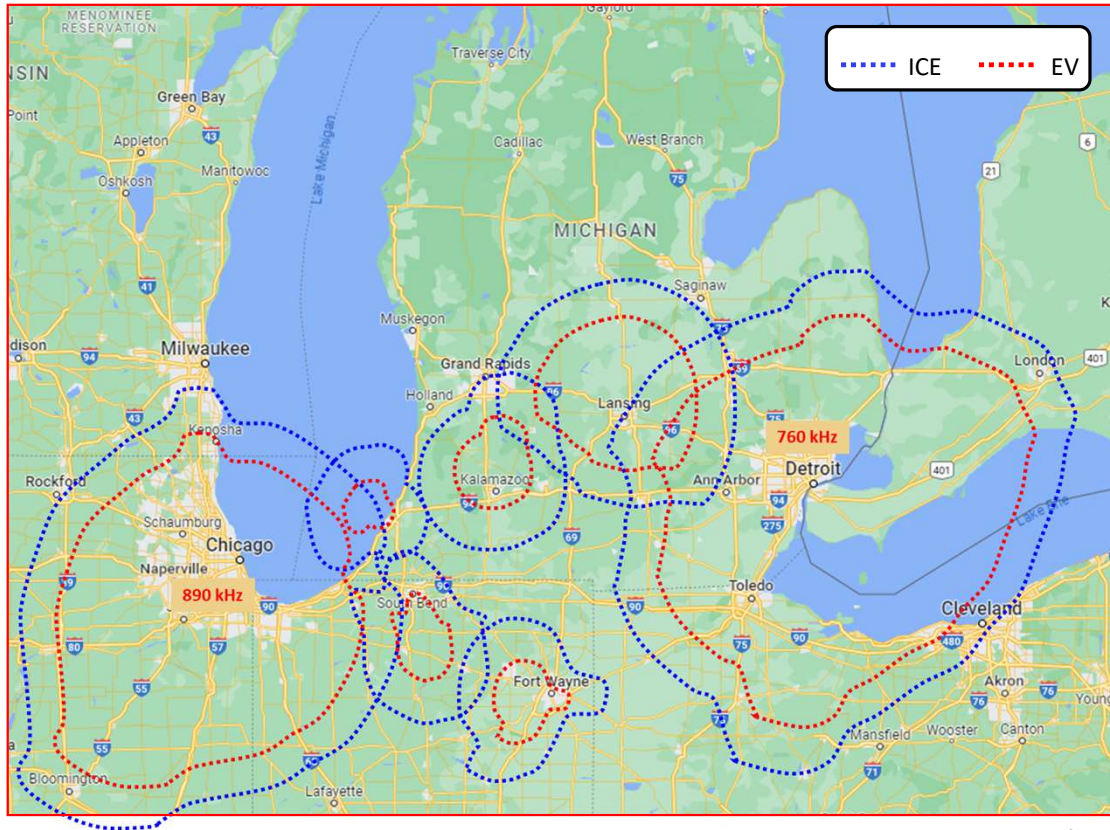
- Emergency alerts at the national level (White House, FEMA, NOAA) are communicated are sent via Primary Entry Point (PEP) stations satellite and internet communications.
- State Primary stations (AM, FM) monitor these sources and cascade emergency alerts to designated “Local Primary” stations (AM, FM) who then cascade to other participant stations(AM, FM, TV).
  - Participation is mandatory for national alerts, but voluntary for local alerts.
  - In Michigan there are 375 licensed AM stations and 144 licensed FM stations.

Source: FCC.gov



# ESA Review

- WJR and WLS are EAS PEP stations. The other AM stations shown are monitoring one or both PEP stations plus other sources.
- The contours would suggest that emergency alerts may not be receivable in all areas of Michigan

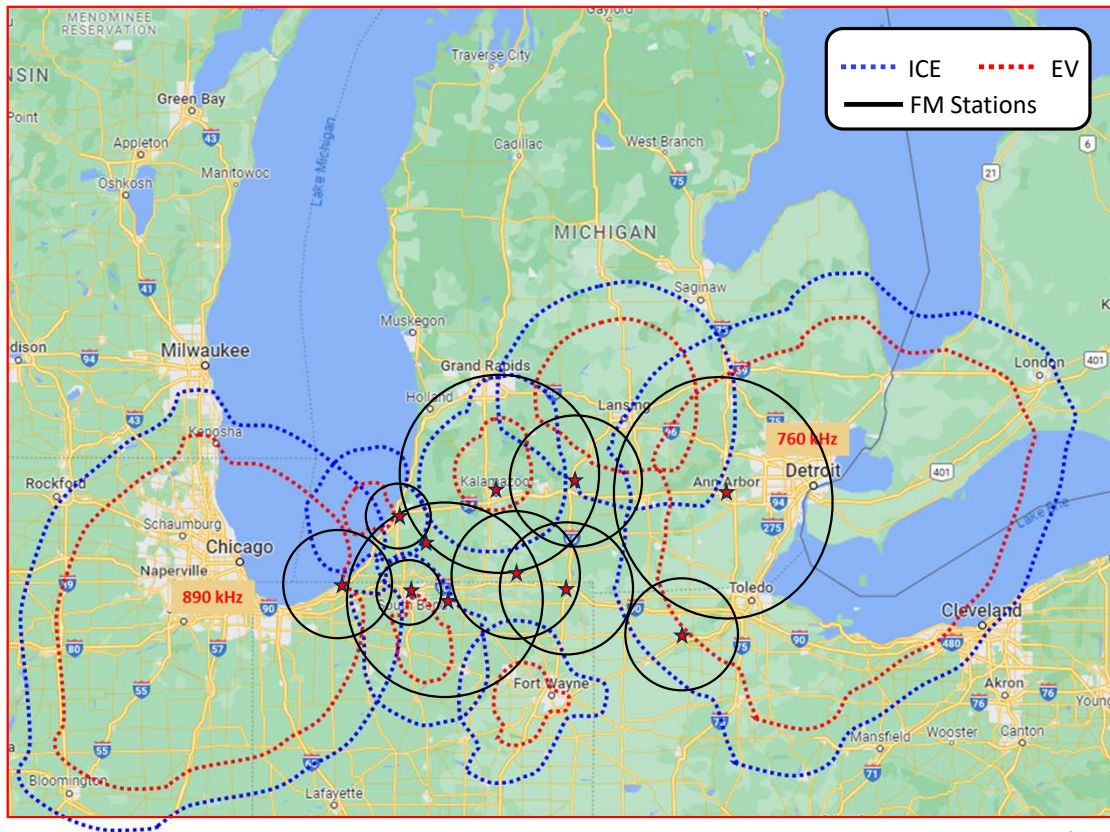


Sources: [zipsignal.v-soft.com](http://zipsignal.v-soft.com)  
[radiocator.com](http://radiocator.com)

# EAS Review

- The black contours illustrate the inclusion of several (not all) FM stations across the state.
- Similar coverage in most states.
- Reception is possible but does require tuning to a different station (AM or FM).
- If equipped, SXM radio channels 1 and 182 provide the same information without charge to the customer.

EV Impact to EAS is not expected!



Sources: [zipsignal.v-soft.com](http://zipsignal.v-soft.com)  
[radiocator.com](http://radiocator.com)

# Summary

Interference to AM radio reception from the EV powertrain is fully understood

Impact on AM listenership is not expected.

- Local stations not affected.
- Adoption of alternative media sources are increasing
- Many AM stations are simulcasting on FM or offering streaming services

EAS impact is not expected.

H.R.3413, S.1669 still pending

# H.R.3413

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## Shown Here:

Introduced in House (05/17/2023)

**AM Radio** for Every Vehicle Act of 2023

This bill requires the Department of Transportation (DOT) to issue a rule that requires all new motor vehicles to have devices that can access **AM** broadcast stations installed as standard equipment. (**AM** broadcast stations are often used to deliver emergency alerts and news and entertainment programming; some newer vehicles do not include **AM** equipment.)

Specifically, this bill applies to motor vehicles manufactured in the United States, imported into the United States, or shipped in interstate commerce after the rule's effective date.

The DOT rule must require all such vehicles to have devices that can receive signals and play content transmitted by **AM** broadcast stations or digital audio **AM** broadcast stations installed as standard equipment.

Prior to the effective date of the rule, manufacturers that do not include devices that can access **AM** broadcast stations as standard equipment must inform purchasers of this fact through clear and conspicuous labeling.

DOT may assess civil penalties against any manufacturer that fails to comply with the mandate. The Department of Justice may also bring a civil action to enjoin a violation.

Further, the Government Accountability Office must study and report on whether a reliable alternative communication system exists for delivering emergency alerts and consider the (1) cost to drivers and passengers of receiving communications through an alternative system, and (2) cost and time required to develop and implement an alternative.



# Thank You

