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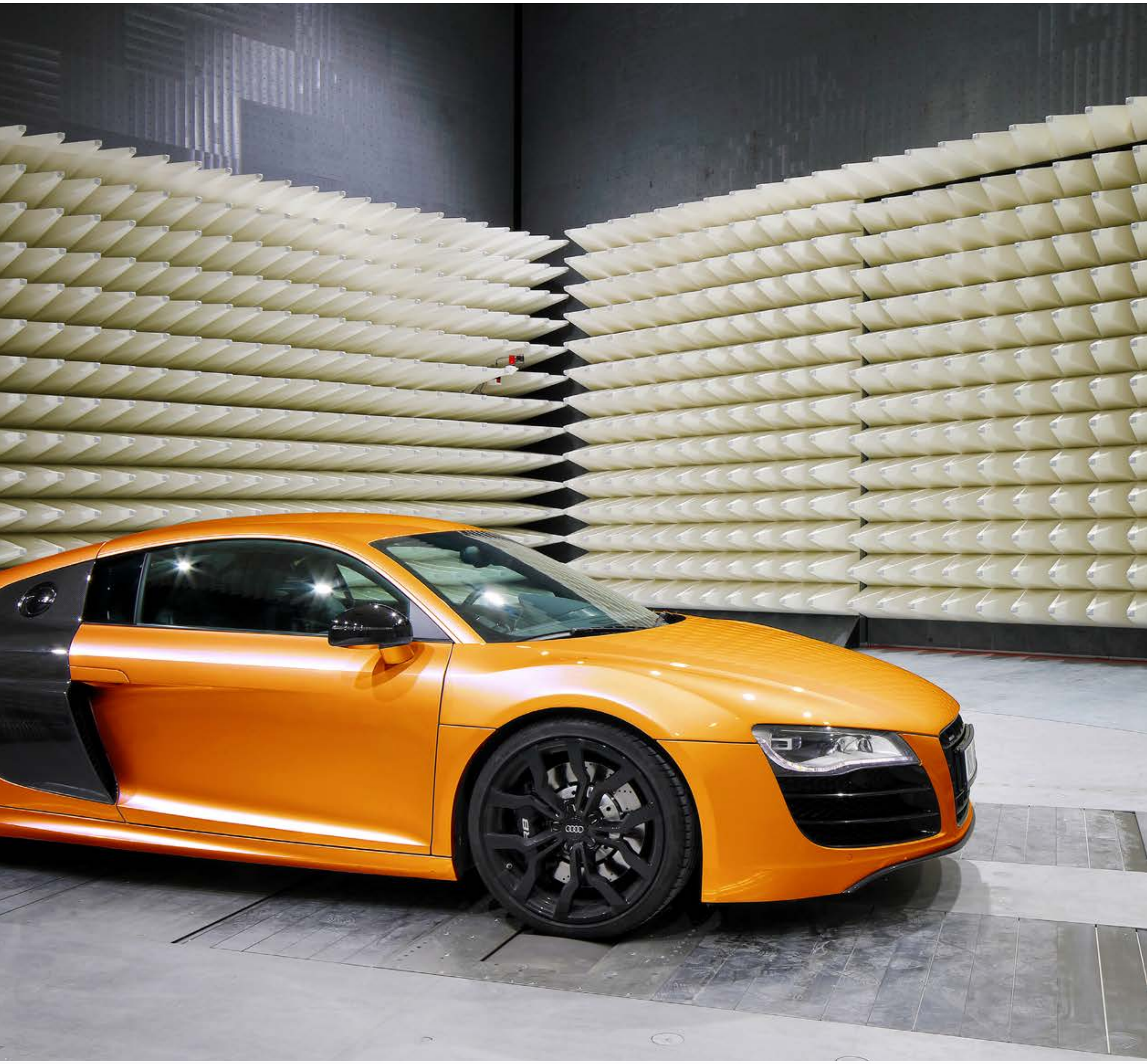
2019 AUTOMOTIVE EMC GUIDE



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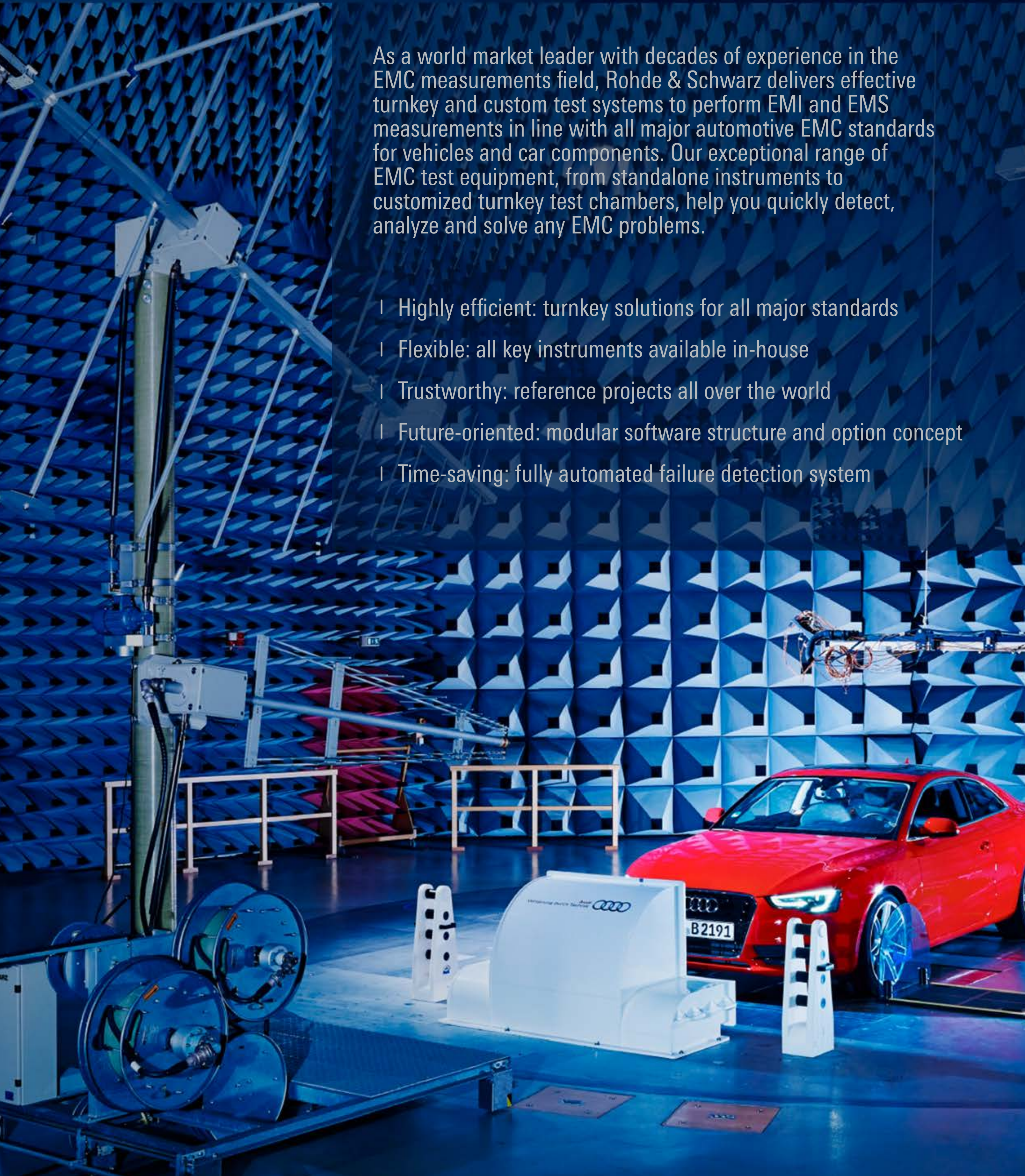
Make ideas real



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EMC EQUIPMENT MANUFACTURERS MATRIX

The following chart is a quick reference guide of test equipment and includes everything you'll need from the bare minimum required for key evaluation testing, probing, and troubleshooting, to setting up a full in-house precompliance or full compliance test lab. The list includes amplifiers, antennas, current probes, ESD simulators, LISNs, near field probes, RF signal generators, spectrum analyzers, EMI receivers, and TEM cells. Equipment rental companies are also listed. The products listed can help you evaluate radiated and conducted emissions, radiated and conducted immunity and a host of other immunity tests, such as ESD and EFT.

EMC Equipment Manufacturers		Type of Product/Service													
Manufacturer	Contact Information - URL	Antennas	Amplifiers	Near Field Probes	Current Probes	Spectrum Analyzers/EMI Receivers	Software Simulation	ESD Simulators	LISNs	Radiated Immunity	Conducted Immunity	Pre-Compliance Test	TEM Cells	Rental Companies	RF Signal Generators
A.H. Systems	www.ahsystems.com	X	X		X							X			
Aaronia AG	www.aaronia.com	X	X			X						X			
Advanced Test Equipment Rentals	www.atecorp.com	X	X			X		X	X	X	X	X		X	X
Altair	www.altair.com						X								
Amplifier Research (AR)	www.arworld.us/	X	X			X			X	X	X	X			X
Anritsu	www.anritsu.com					X						X			X
AR RF/Microwave Instrumentation	www.arworld.us	X	X	X						X	X			X	
Beehive Electronics	www.beehive-electronics.com			X								X			
Electro Rent	www.electrorent.com		X			X		X	X	X	X	X		X	X
Coilcraft	www.coilcraft.com	X	X												
CST Computer Simulation Technology GmbH	www.cst.com						X								
EM Test	www.emtest.com										X	X	X		
EMC Partner	www.emc-partner.com							X			X				
Empower RF Systems	www.empowerrf.com		X							X					
ETS-Lindgren	www.ets-lindgren.com	X	X	X	X				X	X	X	X	X		X
Fischer Custom Communications	www.fischercc.com			X	X				X			X			
Gauss Instruments	www.gauss-instruments.com					X									

EMC Equipment Manufacturers		Type of Product/Service													
Manufacturer	Contact Information - URL	Antennas	Amplifiers	Near Field Probes	Current Probes	Spectrum Analyzers/EMI Receivers	Software Simulation	ESD Simulators	LISNs	Radiated Immunity	Conducted Immunity	Pre-Compliance Test	TEM Cells	Rental Companies	RF Signal Generators
Haefley-Hippotronics	www.haefely-hipotronics.com							X			X				
Instrument Rental Labs	www.testequip.com		X			X		X	X	X	X	X		X	X
Instruments For Industry (IFI)	www.ifi.com		X							X	X				
Keysight Technologies	www.keysight.com			X		X			X			X			X
Microlease	www.microlease.com		X			X		X	X	X	X	X		X	X
Milmega	www.milmega.co.uk		X							X	X				
MVG	www.mvg-world.com	X													
Narda/PMM	www.narda-sts.it	X	X			X			X	X	X	X			
Noiseken	www.noiseken.com							X			X	X			
Ophir RF	www.ophirrf.com		X								X				
Pearson Electronics	www.pearsonelectronics.com				X										
Rigol Technologies	www.rigolna.com			X	X	X						X			X
Rohde & Schwarz	www.rohde-schwarz.com	X	X	X	X	X			X	X	X	X			X
Siglent Technologies	www.siglent.com/			X		X						X			X
Signal Hound	www.signalhound.com			X		X						X			X
TekBox Technologies	www.tekbox.net		X	X					X			X	X		
Tektronix	www.tek.com			X		X						X			
Teseq	www.teseq.com		X		X			X		X	X	X	X		
Test Equity	www.testequity.com/leasing/		X			X		X	X	X	X	X		X	X
Thermo Keytek	www.thermofisher.com							X			X				
Thurlby Thandar (AIM-TTi)	www.aimtti.com					X						X			X
Toyotech (Toyo)	www.toyotechus.com/emc-electromagnetic-compatibility/	X	X			X			X	X		X			
TPI	www.rf-consultant.com														X
Transient Specialists	www.transientspecialists.com									X	X		X		
TRSRenTelCo	www.trsrentelco.com	X	X			X			X	X	X	X		X	X
Vectawave Technology	www.vectawave.com		X												
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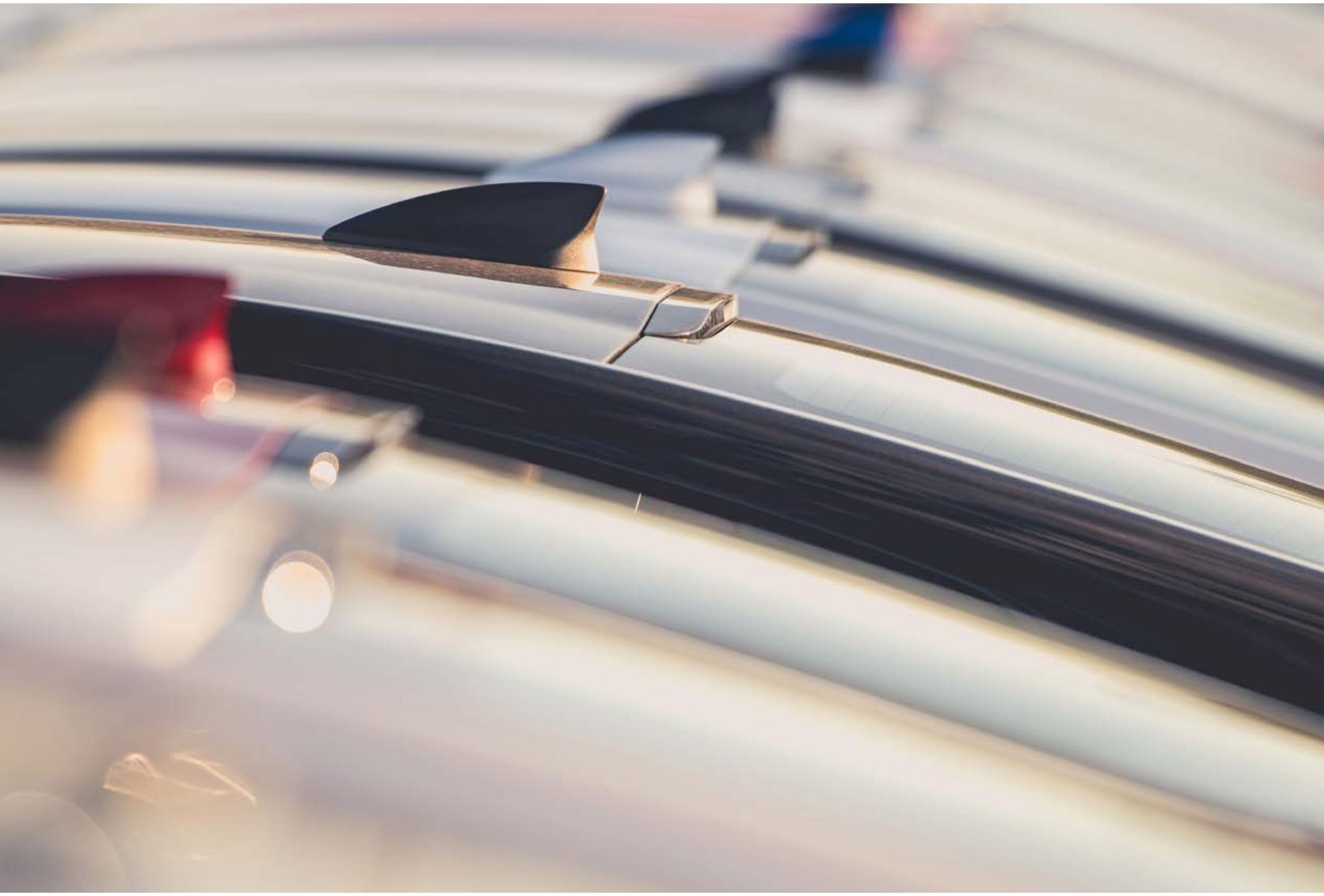
CONTROLLING EMI IN HIGH-SPEED PCB DESIGN

Patrick Carrier
Mentor Graphics, a Siemens Business



CONTROLLING EMI IN HIGH-SPEED PCB DESIGN

Antennas come in all shapes in sizes. In addition to wireless communications, they are becoming ubiquitous in the automotive space as well. Similarly, very high-speed digital circuits are pervading these realms. It is the unintentional creation of antennas in these high-speed digital circuits that cause electromagnetic interference (EMI) issues. One of the main goals in designing a high-speed circuit is to make it a very poor antenna; in other words, make sure all currents are travelling in a closed loop. The ramifications of failing to doing so include failing emissions requirements, increased susceptibility to outside noise sources, and unreliable circuit operation.

Designing a digital circuit with closed current loops seems simple enough, but where are the loops? The answer to that depends on a few factors, including whether the circuit is doing a 0-to-1 or 1-to-0 transition, how the transmission lines are referenced, and where the decoupling capacitors are located. In *Figure 1* below, we examine the current loops for a fairly common case. An I/O buffer is connected to a transmission line that is referencing both power and ground planes. In a 0-to-1 transition, current is going to come from the power pin to the power plane connected to the buffer, down through the pull-up transistor, out onto the trace, where it will couple onto both planes. It will then flow on the ground plane back to the ground pin, and on the power plane through the decoupling capacitors to ground.

We often refer to the currents in the planes as return current. They are the result of energy coupled from the trace to the planes through electromagnetic waves. The potential of the planes does not matter. Whether they are a ground plane or a voltage plane, at any given instant, the trace will be coupling energy into its reference planes. It will actually couple energy onto whatever are the nearest pieces of metal, but in most well-designed PCBs, those are usually planes. If those planes happen to be

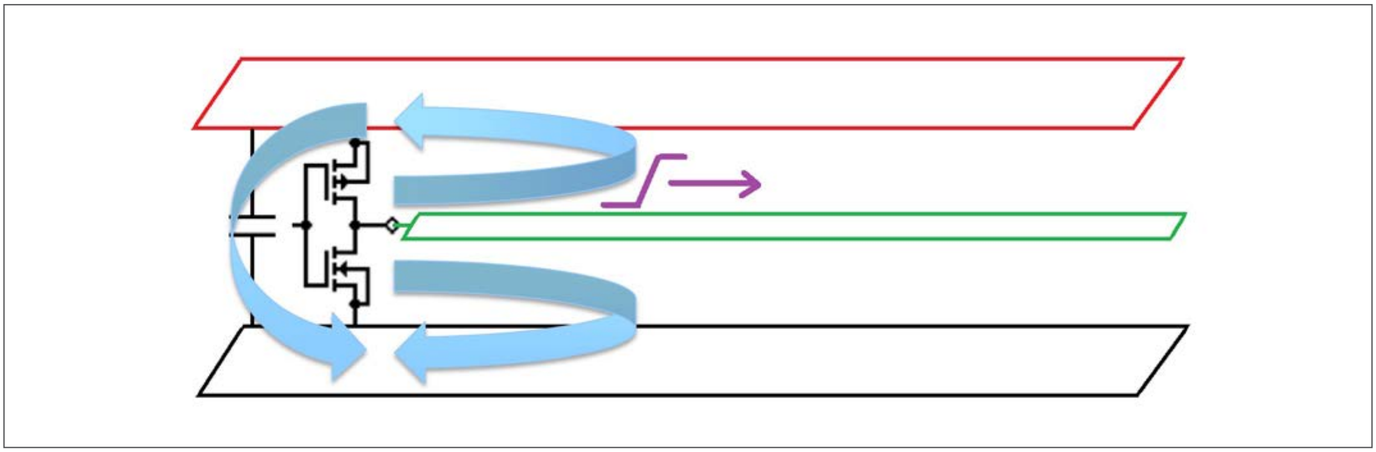


Figure 1. Current loops in a high speed digital circuit.

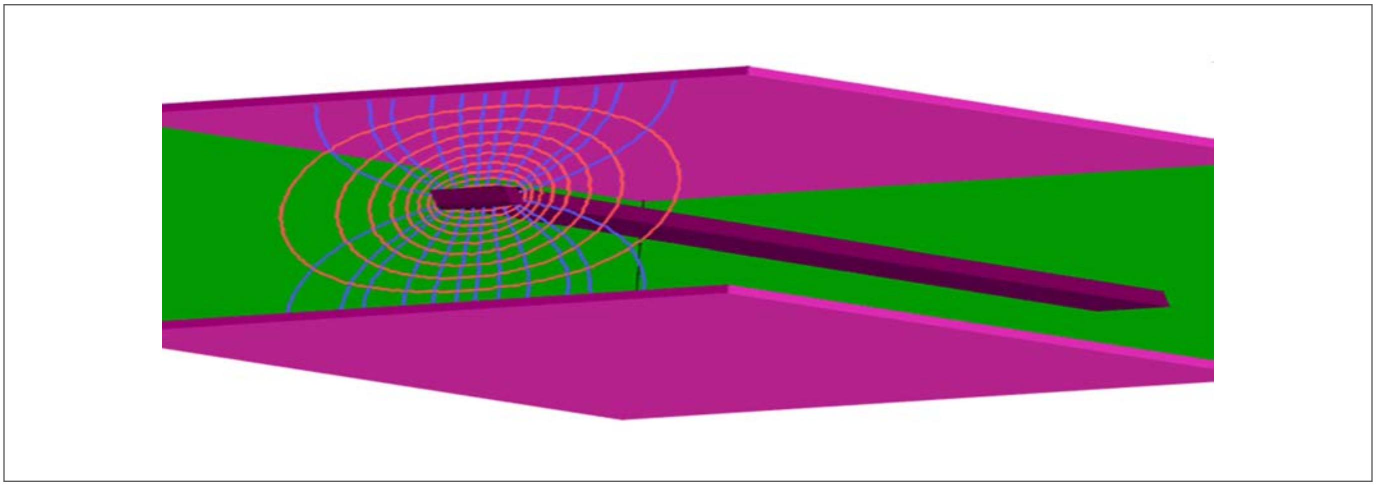


Figure 2. Field coupling of a trace and its reference planes.

the power and ground planes used by I/O buffers driving that trace, that is the best case, as it best facilitates a complete loop for the return current. *Figure 2* depicts the field coupling between a trace and its reference planes. That coupling determines the electrical properties of the trace, like the impedance of the trace. It can be described as inductance and capacitance per unit length. As the signal travels down the line, it is effectively charging up each of those LC circuits, and then moving on to the next one, charging that one up, and so on. Any break in that circuit will cause radiation to occur. Obviously, you wouldn't expect the circuit to work if you cut the trace (other than it acting like an antenna). A cut in the reference part of that loop can have the same effect. It is important to remember that a transmission line is a combination of a trace and its reference plane, and keeping them both in good shape will eliminate most EMI problems. The best way to avoid creating unintentional antennas is to keep the return current adjacent to the trace and on the reference plane(s).

There are a number of ways to work around traces crossing reference plane splits. Of course, it would be best to route all signals referenced to a solid ground plane, but board thickness and cost concerns often do not allow this. However, through careful stackup planning, you can route slower signals against any power planes that will be split up among multiple different voltages. Even if this is done, it usually involves a dual stripline trace structure, which utilizes two reference planes for two trace layers. A trace will be more closely coupled to its nearer reference plane, allowing it to cross a split in the further reference plane. The return current distribution scales linearly with the distance of the trace to its reference plane. So, if a trace is 4 times closer to its nearer reference plane than the further plane, that plane will have 4 times the return current.

A common method used to minimize radiation from traces crossing plane splits is to stitch the planes together in the vicinity of the trace crossing using decoupling capacitors. This can be somewhat effective, however, it is important to note that a mounted capacitor does not act as a low impedance across a wide frequency band, so it will not eliminate the radiation issue.

Less extreme but equally problematic are situations where the return current path is not completely broken but compromised. A common example of this is the case of a signal transitioning between layers using a via. As the signal transitions, there needs to be some path for the trace return current to connect between reference planes. If the trace is transitioning between layers where the reference planes are the same potential, such as all ground referencing, such a path can be created using a stitching via. If, however, the referencing changes from all ground to all power, the planes must be stitched together using a bypass capacitor or, better yet, a network of bypass capacitors. Such a network of capacitors is already present in the design as part of the power distribution network (PDN). Decoupling capacitors are connected between power and ground, usually in the vicinity of the IC, so if a layer transition has to be made, it is best to make that transition near an IC where these capacitors are. Another way of looking at that is to "pick a layer and stick with it;" in other words, make the layer transition at the IC and continue the route on that layer until it is at another IC.

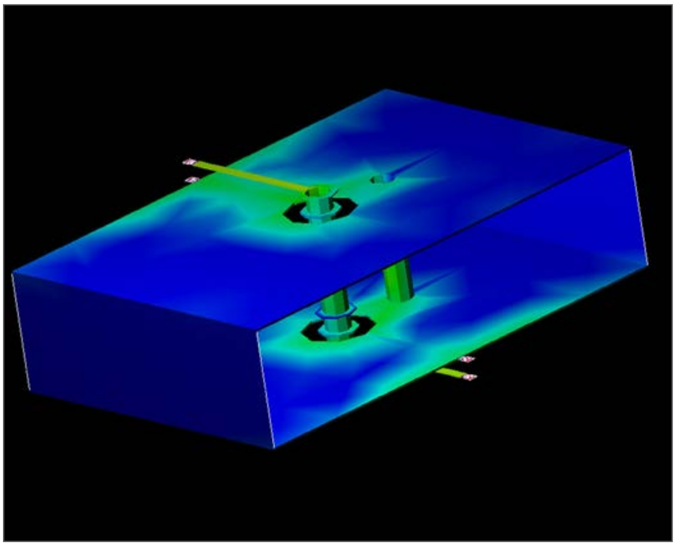
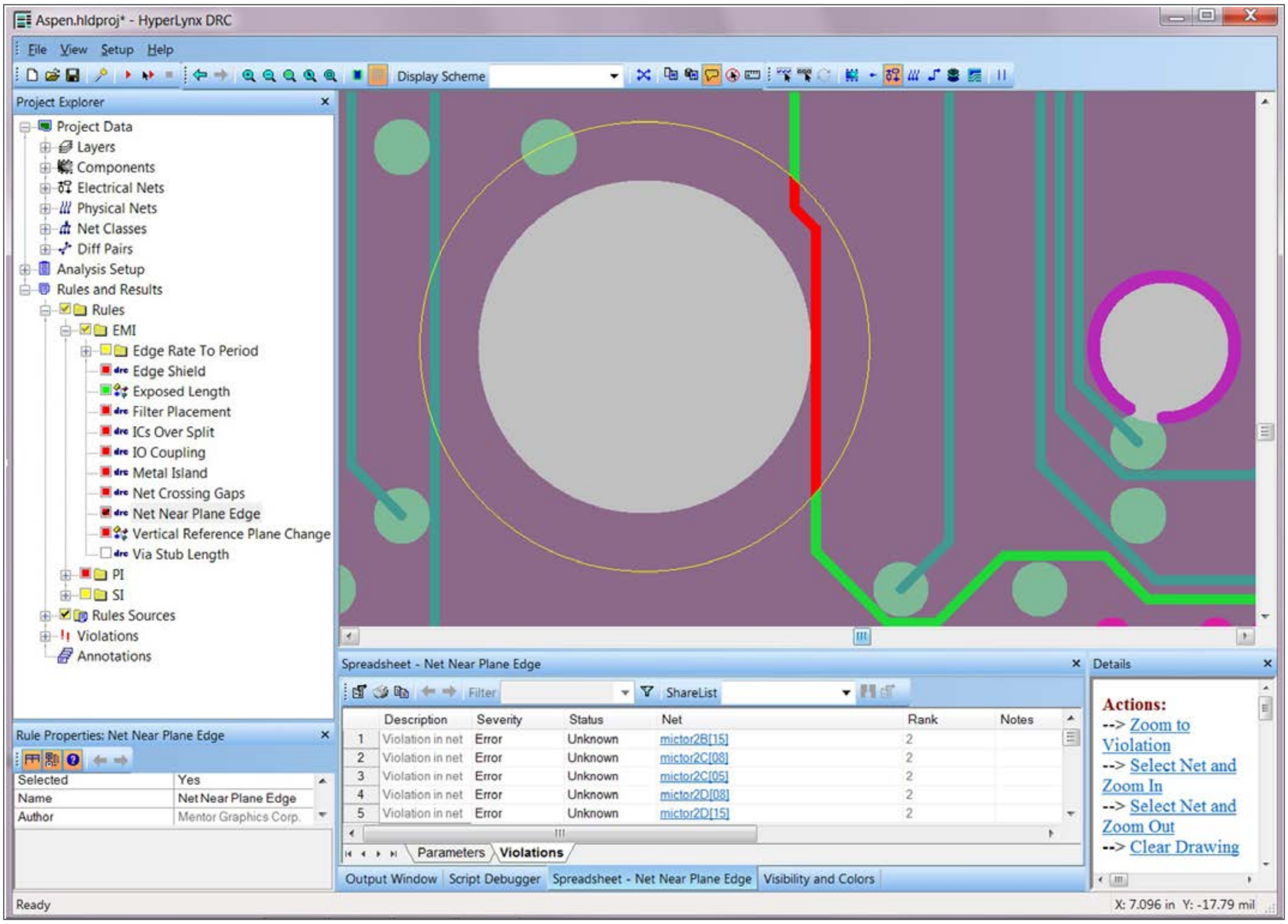


Figure 3. Current distribution for a signal via with a nearby transition via.

Another example of a compromised return path is a signal being routed close to the edge of a reference plane. Not only does this change the impedance of the trace, but it also will cause some radiation and make the signal more susceptible to noise. Issues like this can be difficult to find in a layout, as they often result from regular voids in the planes from via antipads and mounting hole clearances.

Finding such issues often requires a tedious manual design review of the layout. But these issues can be found quickly, using an automated design rule checking tool such as HyperLynx DRC. An example is shown in *Figure 4*. Such design rule checks can be automated and customized to go beyond just a simple check of a trace near a hole, to include an understanding of return current distribution near a plane edge.

Other issues can be found through automated inspection as well, such as the low-inductance connection of decoupling capacitors in the vicinity of the power and ground pins of an IC. Decoupling capacitors are needed at ICs to complete the return current loop even if there are no splits in the plane. This can be seen in *Figure 1*, where the decoupling capacitors are depicted as a single capacitor. If the trace is located symmetrically between the two planes, half of the return current will flow into the power plane and need to make its way to the ground pin. This is where decoupling capacitors placed at the IC allow that current to flow from the power plane to the ground pin. That makes decoupling capacitors as essential to controlling EMI as they are for maintaining power integrity.



Selected	Yes
Name	Net Near Plane Edge
Author	Mentor Graphics Corp.

	Description	Severity	Status	Net	Rank	Notes
1	Violation in net	Error	Unknown	mictor2B[15]	2	
2	Violation in net	Error	Unknown	mictor2C[08]	2	
3	Violation in net	Error	Unknown	mictor2C[05]	2	
4	Violation in net	Error	Unknown	mictor2D[08]	2	
5	Violation in net	Error	Unknown	mictor2D[15]	2	

Actions:
--> Zoom to Violation
--> Select Net and Zoom In
--> Select Net and Zoom Out
--> Clear Drawing

Figure 4. Trace near reference plane edge identified and highlighted in HyperLynx DRC.

EMI issues are related to both power integrity and signal integrity. An inadequately designed PDN will lead to radiated emissions, usually corresponding to the high-impedance points of the PDN profile. For signals, if a signal is radiating energy, that also means that energy is not making it to the receiver, causing a signal integrity issue. This is usually manifested as edge degradation. Signal and power integrity issues are usually solved through analysis and subsequent design changes. Solving EMI issues involves ensuring complete current loops, which can be accomplished through careful inspection of the board. Reviewing all possible EMI issues on a board can be complicated and time-consuming, and made more practical by the use of automated design rule checks. A combination of analysis and careful design review will keep you from creating unwanted antennas on the board, and leave your high speed interfaces running reliably and working well with the antennas that are supposed to be there.

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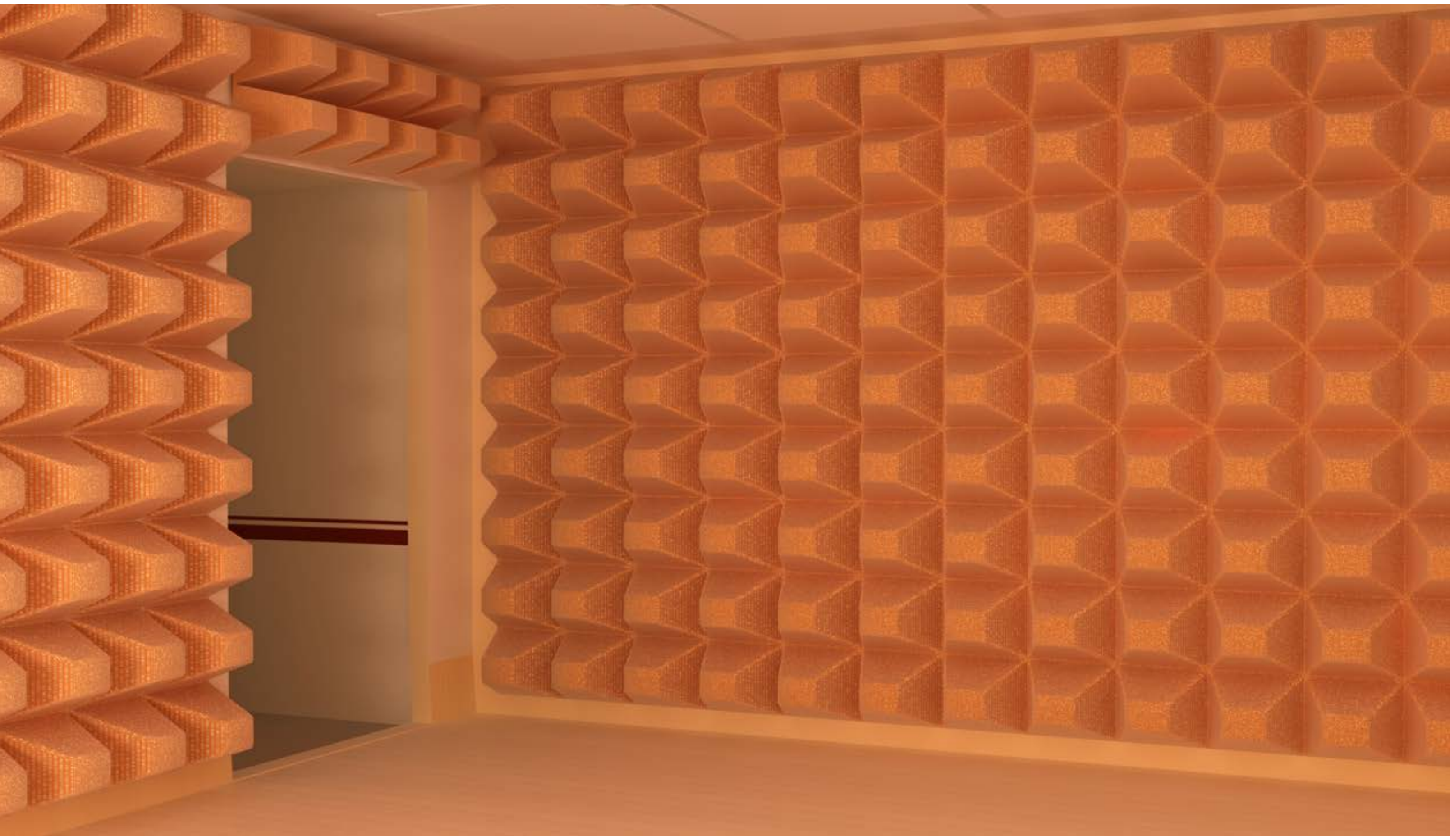
DETERMINING SEMI-ANECHOIC CHAMBER RESONANCE AS A SOURCE OF RADIATED EMISSION MEASUREMENT VARIATION BETWEEN CHAMBERS AND COMPARING TO OATS MEASUREMENTS

By David A. Weston
EMC Consulting, Inc.



DETERMINING SEMI-ANECHOIC CHAMBER RESONANCE AS A SOURCE OF RADIATED EMISSION MEASUREMENT VARIATION BETWEEN CHAMBERS AND COMPARING TO OATS MEASUREMENTS

INTRODUCTION

This article describes the lack of an acceptable correlation between anechoic chamber and open field test site radiated emission measurements, which were described in *Reference 1* in 2000, as well as a lack of correlation between chambers. It was found that emission measurements, which were over the limits in one facility, would pass in another.

The lack of a good correlation between open area test site (OATS) and chamber measurements and between chambers means that manufacturers may be over designing equipment for EMC, or equipment is passing radiated emissions at one site but would fail at another.

Although this would appear to be of great interest to manufacturers, up until now this has not been the case. It is not surprising when a manufacture tries a different facility for radiated emission or susceptibility (immunity) measurement in the hope that the equipment will pass in the second facility, where resonances may be lower or at different frequencies.

CASE STUDIES

The report in *Reference 1* report compared the test results over the 212 to 236 MHz frequency range between a 3 m OATS, a 3 m anechoic chamber, and a 10 m OATS. The same EUT was tested on all sites and it was determined that, although often a determining factor, the cable orientation was not the cause of the large variation which was seen.

The normalized site attenuation (NSA) of the 3 m OATS in *Reference 1* was measured from 200 to 300 MHz and the variation was 0.31 to 1.9 dB. Whereas the difference in measured level between the 3 m anechoic chamber and the 3 m OATS was as high as 14 dB. At some frequencies emissions were seen at one site and not at another and ambients were ruled out. This represented an error of up to 25 dB!

In radiated emission measurements on the aforementioned 3 m OATS at 10 m, reported in *Reference 2* in 2010, the EUT manufacturer's customer had the same EUT measured in a 3 m semi-anechoic chamber with a very high 26.8 dB variance between the OATS and the chamber. *Table 1* shows the difference in measured levels between the OATS and chamber and it can be seen that the emissions were much higher in the chamber at some frequencies. Also some levels measured on the OATS were not seen at all in the chamber, indicating a frequency where the fields inside the chamber cancel.

Frequency (MHz) V = Vertical H = Horizontal	10m OATS dBuV/m	3m chamber dBuV/m	Delta (dB)
192V	13.5	40.3	26.8
192H	20.5	47.2	26.7
576V	25.1	40	14.9
576H	43.1	45.9	2.8

Table 1—The same EUT measured on a 10 m OATS versus the emissions measured in a 3 m chamber with a 10.5 dB correction from the 10 m to the 3 m measurements.

Even when the EUT was measured on a second 10 m OATS, with a good correlation to the first 10 m OATS, the customer insisted that the measurements made in the chamber were correct. The manufacture had to achieve emissions 6 dB below the limit and so a massive margin was required in order to get the equipment to pass the customers measurement in the semi-anechoic chamber. This resulted in added engineering and manufacturing cost to the manufacturer. It also added the frustration in knowing that the EUT had almost certainly passed the requirements and a delay due to numerous levels of re-engineering.

OATS AND CHAMBER NORMALIZED SITE ATTENUATION CALIBRATION

ANSI C63.4 defines the theoretical NSA for site validation. The requirement is met when measurements show that the site NSA is within the range of +/-4 dB of the theoretical. The antenna calibration method may affect the antenna calibration and therefore the NSA value. ANSI C63.5:2006 is cited in ANSI C63.4:2014 as the only permissible antenna calibration standard which includes requirements for antennas used for NSA measurements. Antenna uncertainty values may result in not achieving the required +/-4 dB range but not the huge variation between some semi-anechoic chamber and OATS measurements.

ANSI C63.4 describes the standard OATS as well as alternative test sites which include RF absorber lined metal test chambers (semi-anechoic chambers), office or factory buildings, and weather protected OATS with covering structures. These alternative test sites shall comply with the volumetric NSA requirements of the standard over a volume occupied by the EUT, or the EUT arrangement. Thus the NSA measured on the OATS and the anechoic chamber measurements over this volume should be comparable, which is often not the case.

POSSIBLE SOURCES OF ERROR

The cable orientation and time spent in maximizing cable emissions plays a role but surely not to the extent of 25 and 26.8 dB as in the two examples. Also at high frequency where emissions may be sourced by seams in the enclosure the speed of the turntable does plays a role in detecting the emissions which occur over a narrow beam width. The correction of 10.5 dB in going from a 10 m to a 3 m measuring distance is also not always correct, especially for large EUTs. Some test facilities make radiated emission measurements to commercial requirements, such as FCC Part 15 and EN55022, on class A equipment in a 3 m chamber and then make the correction to 10 m with a possible error.

CHAMBER RESONANCES

The major source of variation in anechoic chamber measurements is chamber resonances resulting in variation in the electric field level within the chamber. The chamber is an enclosed box with reflective surfaces in which any electromagnetic wave bounces back and forth inside it, several resonant modes are generated and energy is stored within the chamber. These resonant modes generate standing waves and minimums and maximums in the field occur depending on frequency and location within the chamber. At resonance the field within the room may be higher than the field generated by the source in an open area test site. Several resonant modes may occur and when the room is lined with absorber these resonances are partially attenuated by the absorber.

ABSORBER

Likewise with absorber the reflections within the room are partially damped. However the attenuation due to the absorber is limited.

The absorber inside the room has to be effective enough to achieve the NSA requirement. The NSA calibration is made at the frequencies shown in *Table 2.*

f (MHz)	f (MHz)
30	160
35	180
40	200
45	250
50	300
60	400
70	500
80	600
90	700
100	800
120	900
140	1000

Table 2—NSA calibration frequencies.

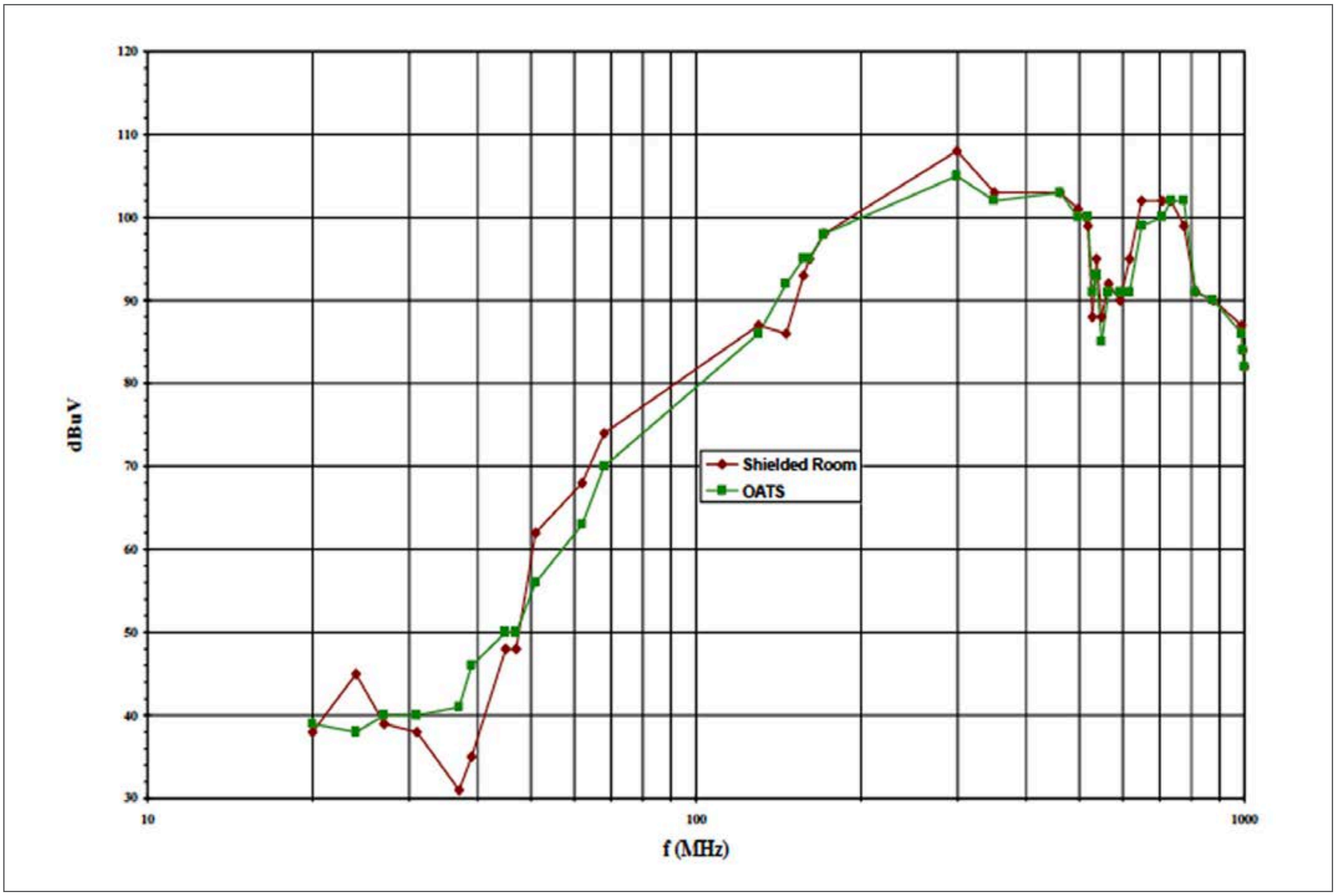


Figure 1—Chamber to Open Area Test site correlation from 20 MHz to 1 GHz for a horizontally polarized field generated by a 10cm bow tie antenna and measured using a log periodic/biconical antenna compared to the Open Area Test Site measurement.

The interval between frequencies is acceptable for testing on an OATS but we see that a typical resonance in a room covers only approximately 4 MHz, from *Figure 1,* and so in performing the NSA test any resonance may be missed if this falls between the spot frequencies tested for NSA.

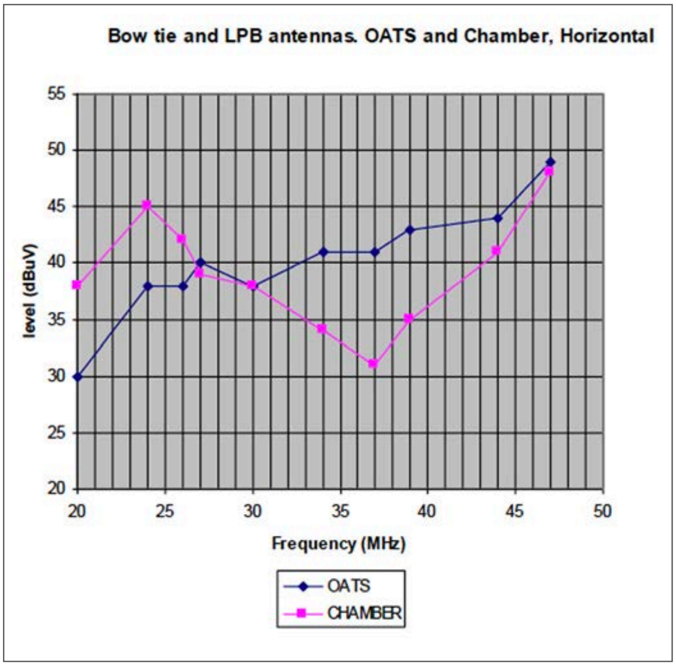


Figure 2–Chamber resonance for horizontally oriented field generated by a 10cm bow tie antenna and a log periodic/biconical antenna compared to the Open Area Test Site measurement.

We saw that the field polarization affected the room resonance and *Figure 3* shows the correlation for a vertically polarized field from 20 to 50 MHz.

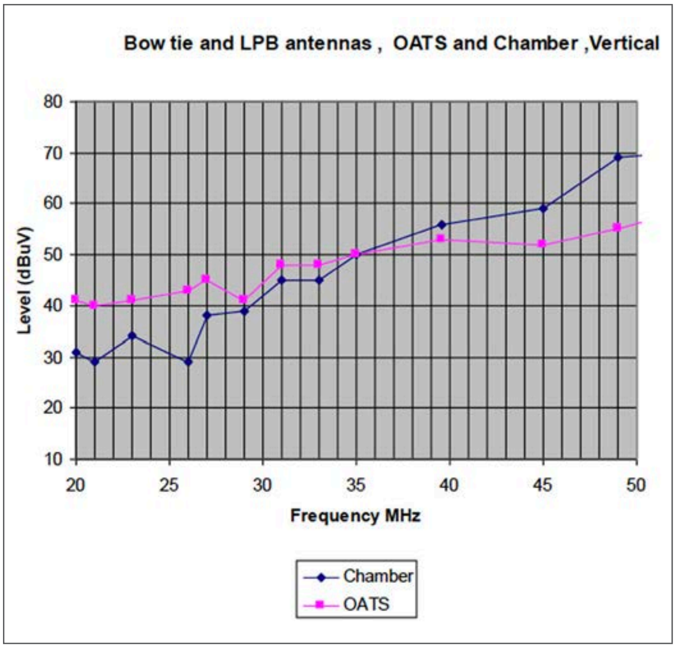


Figure 3–Chamber resonance for vertically polarized field generated by a 10cm bow tie antenna and a log periodic/biconical antenna compared to the Open Area Test Site measurement.

TYPE OF ABSORBER

The type of absorber plays a large role in damping the resonances as seen in *Reference 3*. *Reference 3* identifies the influential parameters in CISPR 25 radiated emission setup. CISPR 25 is the reference standard in the automotive industry for performing measurements in a semi-anechoic chamber. Unlike other commercial radiated emission measurement, but similar to a MIL-STD-461 type test, the EUT is placed on an elevated ground plane connected to the chamber wall. Significant differences were seen between CISPR 25 compliant laboratories when measuring emissions on the same device under test. The paper makes an inter laboratory comparison across 17 laboratories with a special focus on the 30 to 100 MHz frequency range. A three dimensional model of the semi-anechoic chamber was built and validated to analyze the influence of each of the parameters of the room and provide a reference for the measurements in the laboratories.

CISPR25 requires that the material absorption performance shall be greater than 6 dB in the 70 to 2,500 MHz frequency range. In a 5.33 x 6.53 x 3.63 m chamber the first cavity resonance is at 36 MHz and so the absorber type used is important over the 30 to 100 MHz frequency range.

These absorbers include ferrite tiles, foam absorbers, or hybrids (a combination of ferrite tiles and absorber which are matched). The ground plane in the CISPR 25 room can be connected either horizontally to the chamber wall or vertically to the floor ground plane. *Reference 3* shows a -20 to +10 dB variation between the two grounding techniques with the greatest variation seen with a vertical grounding. In a room without a ground plane this affect is not seen and it is the absorber type, which is important. Measurements on foam pyramidal absorber and hybrid show the reflectivity of the two, a comparison of which is shown in *Table 3*.

Frequency (MHz)	Reflectivity foam pyramidal (dB)	Reflectivity hybrid (dB)
30	0	11
40	0	13
100	12	12
200	28	11

Table 3–Foam and hybrid absorber reflectivity.

It is surprising that the foam absorber performance at 200 MHz is better than the hybrid, perhaps indicating that the matching of the ferrite and foam is not ideal. When designing a room, such as shown in *Figure 4* with foam mounted on top of ferrite tile, the manufacturer of both types of absorber recommended the types of absorber which were compatible. The effect of the absorber type alone can be extracted from the data for horizontal ground plane connection from *Reference 3*.

In order to perform the inter-laboratory measurements between 17 laboratories, a reference was developed based on simulation with perfect absorbers and with a 1 x 2.5 m elevated ground plane. This reference provides a theoretical maximum and minimum for the absorber types. Over the 5 to 84 MHz frequency range, the maximum variation in measurement results was 15 dB. For the measurements in the chambers a comb generator was used as the source of radiation.

Reference 3 show a plot of the field measured from this source from the 17 laboratories compared to the reference. This plot shows that the largest variation from the reference level was with rooms, which contained only pyramidal foam absorber. This variation was a worst case 34 dB at 20 to 26 MHz with the measurements from rooms with a hybrid absorber lying within the predicted maximum and minimum levels. Thus, based on the measurements the worst-case difference in radiated emission measurements between any two rooms was 22 dB.

Another technique used to achieve the results shown in *Figure 1* and described in *Reference 4*, adds absorber loads placed in the room at strategic locations as well as a compatible combination of ferrite tiles with foam absorber on top, as shown in *Figure 4*, resulting in a very well damped room.

METHODS OF DETERMINING CHAMBER RESONANCES

1. Antenna input power to develop a constant E-field level.

As the gain of the transmitting antenna and antenna factor (AF) of the receiving antenna are dependent on frequency, these factors must be corrected for when calculating the required input power for a given E-field at a specific frequency. A field uniformity test was performed to see if this could be used to identify a standing wave as it is expected that the E-field would vary significantly across the chamber. As these tests are typically performed above 80 MHz the low frequency resonances shown in *Figures 2* and *3* would not be detected.

The field uniformity was tested over the area seen in *Figure 5.* From 80 to 200 MHz, a biconical antenna was used as the transmitting antenna but at a distance of 1m from the receiving antenna it was found that the field from the antenna was not sufficiently uniform. Instead an 80 MHz to 1 GHz double-ridged guide antenna was built which provided acceptable uniformity from the antenna at 1 m when measured on the free space range.

The test in the chamber did not show any large variation in field level over the area of test, which is not surprising, as *Figure 1* shows a good correlation to the OATS above 50 MHz. As the room resonances are at frequencies below 80 MHz, a monopole was used as the transmitting antenna and a small isotropic antenna, shown in *Figure 4,* connected to a detector, digitizer, and fiber-optic driver was used as the receiving antenna as shown in *Figure 6*. As the detector has a logarithmic response the level of E-field was adjusted to be just above the noise floor for maximum sensitivity. The transmitting antenna input power was then adjusted so that the digital number read over the fiber-optic link was constant and therefore the E-field was constant. At 24 MHz a room resonance is seen and indeed the level of input power required for a given E-field level is lower than at 20 MHz. The field was measured at locations 1 to 7 in *Figure 5* and the reduction in input power required for a constant E-field is shown in *Table 4.*

Measurement location	Reduction in antenna input power (dB)
1	17
2	18
3	19
4	18
5	16
6	16
7	16

Table 4–Reduction in input power in changing from 20 to 24 MHz.

When using antennas with a linear frequency response to the field, monitoring the E-field at a constant input power will show either an increase in the level of E-field or a decrease, and so after corrections for gain and AF, the resonance frequencies can be determined. The level of E-field is dependent on location and is typically different for vertically and horizontally polarized fields.

Figure 4–A monopole and small isotropic bow tie antenna in a well-damped chamber.

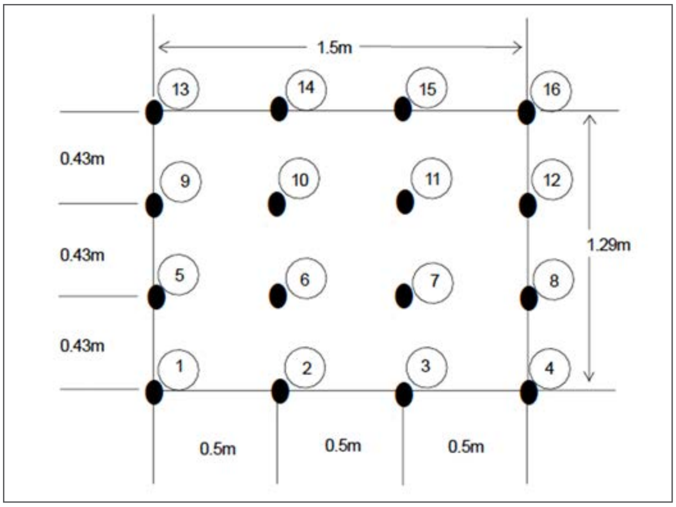


Figure 5 –Area over which measurement of the field uniformity was measured.

2. Comparison between free space range and chamber tests 20 to 50 MHz

The small monopole antenna was used to generate the E-field and a 1 m rod monopole antenna was used as the receiving antenna. The fields generated were thus vertically polarized. The measurements were made with the antennas 1 m apart on a free space range as well as the anechoic chamber. The same cables and signal source were used in both tests and the signal source was located on the ground and covered in a ferrite tile to reduce the impact of the proximity of the signal generator's metal enclosure on the measurement. The ground plane in the chamber was covered in ferrite tiles.

A comparison of the free space results and the chamber results are shown in *Figure 7*. A maximum at 23.7 MHz and a minimum at 30.2 MHz and 42.3 MHz can be seen from the plot. At 23.7 MHz the measured field is 11 dB above the free space measurement and at 30.2 MHz the level is 29 dB lower. Thus, this measurement can be used to identify chamber resonances.

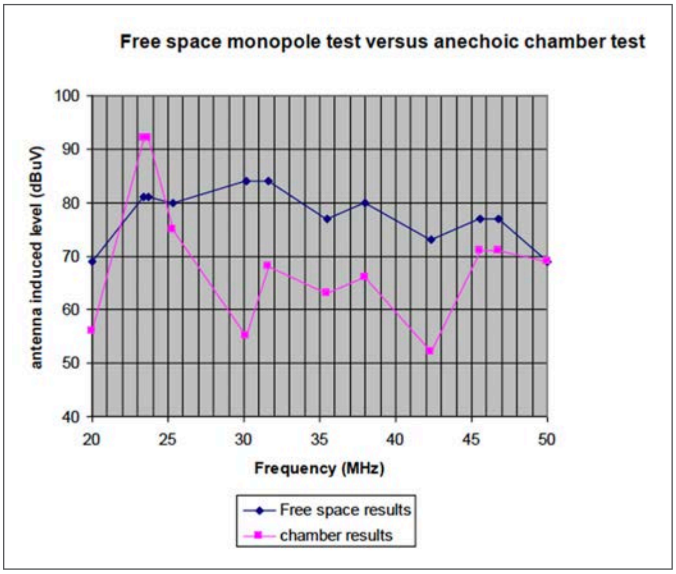


Figure 7–Comparison between anechoic chamber and free space range measurements.

CONCLUSIONS

1. Errors detected

The huge variances seen in the OATS to chamber measurements of 25 dB and 26.8 dB were not seen in the measurements on 17 chamber reported in *Reference 3* but a maximum variation of 22 dB was seen due to the different absorber used. It is possible to attribute the 26.8 dB difference to chamber resonance and poor absorber performance. There may be a simple alternative explanation, however the customer was not willing to make an investigation as he believes his results in the 3 m chamber

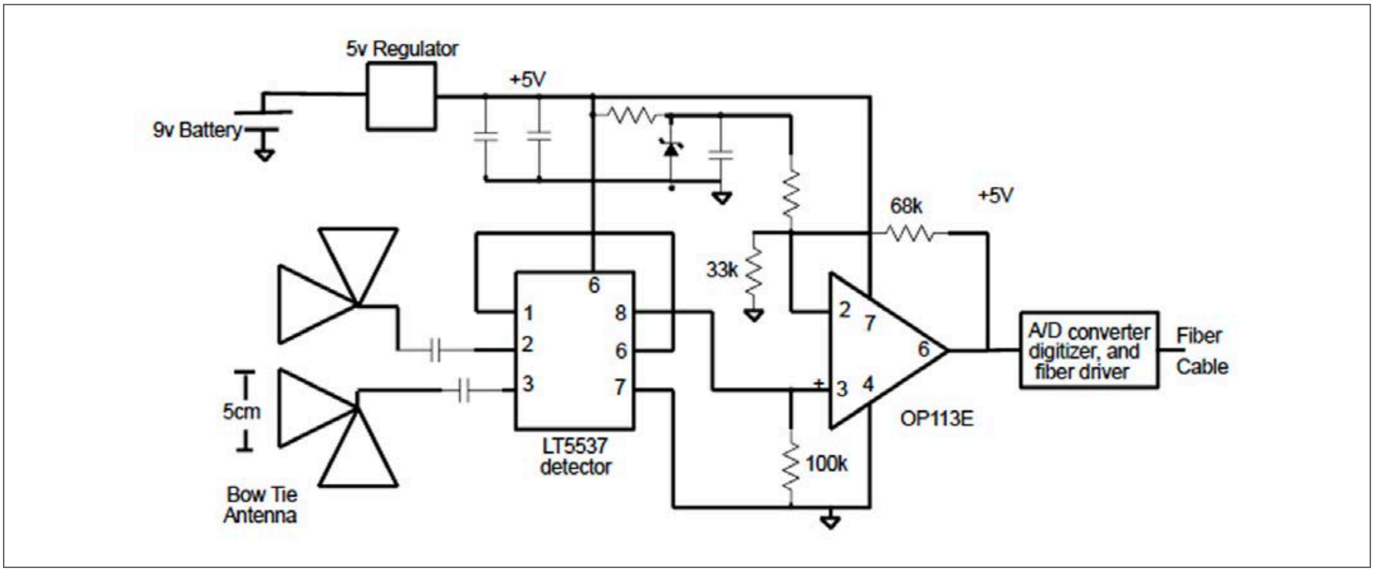


Figure 6–Small isotropic bow tie connected to a detector and digitizer.

were correct. One facility reported a difference of 20 dB over the entire frequency range between measurements on an identical equipment under test (EUT) compared to our measurements. The facility was requested to connect a signal generator to the spectrum analyzer input and indeed the spectrum analyzer measured a 20 dB higher signal than the input level. The spectrum analyzer contained a 20 dB preamplifier, which had been in circuit unknowingly from the day the instrument had been bought! This is most unusual as most instruments automatically correct the displayed level when an internal preamplifier is switched in circuit. If an external preamplifier is used then this may be forgotten in the calculation of the raw data to corrected data.

An error of this type could not be the explanation for the 26.8 dB difference as this positive difference should be seen at all frequencies. Also, it goes without saying that cable attenuation should be a part of the data correction, but would only reduce the measured level by a few dB.

2. Mitigation

Reference 3 does show that a facility with hybrid absorbers exhibits lower resonances than chambers with only foam pyramidal absorbers and so when choosing between facilities this should be a strong contributing factor.

A chamber may be selected before qualification testing by using the monopole antennas, as described, to make a free space or OATS measurement and repeating this in the chamber. Resonance frequencies may be identified in the difference between the measurements. If a free space measurement cannot be performed then an electromagnetic computational program may be used to predict the coupling between the two antennas. However it is important to adequately model the transmitting and receiving antenna cables in the analysis.

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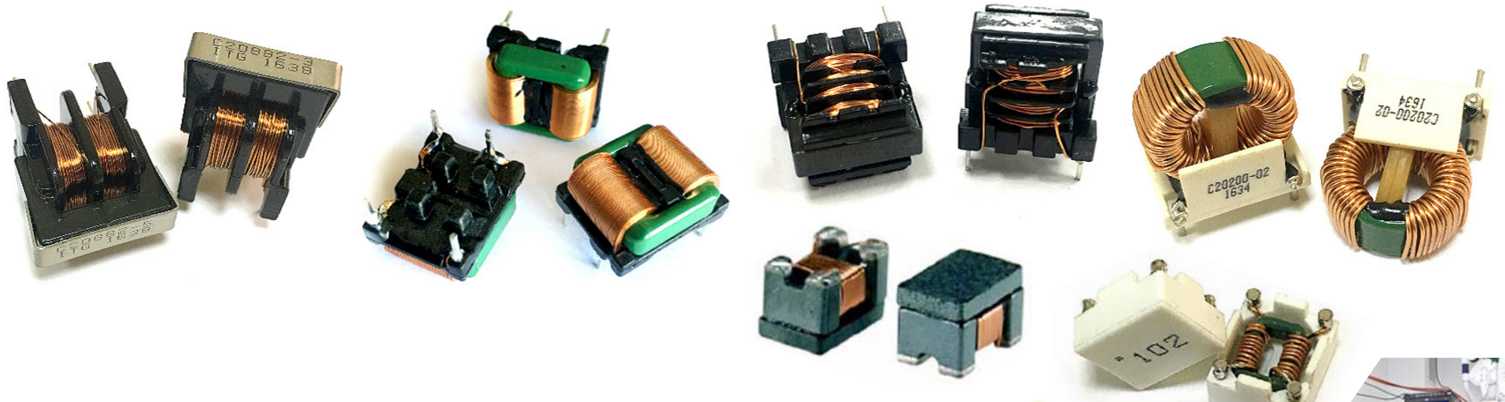

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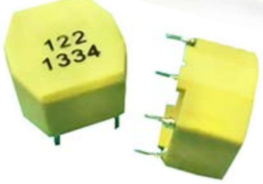

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RESILIENCE IS KEY TO THE CONNECTED AND AUTONOMOUS REVOLUTION

INTRODUCTION

Connected and autonomous vehicles have long been hailed as the answer to safe transport. Around 1.25 million people die in road traffic accidents worldwide each year according to E&T—and driver error accounts for over 90% of those deaths[1]. In theory, the removal of the driver as the lead decision maker for vehicle control should reduce this number, with the SMMT estimating that 2,500 lives will be saved between 2014 and 2032 through the introduction of autonomous vehicles. It is imperative however, that the industry ensures that the control technology underpinning the revolution remains safe, secure and functional as autonomous vehicle development progresses.

Artificial intelligence (AI) technologies, which utilize machine learning, are at the heart of vehicle automation. There have been significant strides in the development of the basic algorithms used in machine learning in addition to an increase in the amount of quality data available. Infrared sensors, light detection and ranging (LiDAR) systems, 360° vision systems, wireless connectivity and many more data sources all combine to provide machine learning algorithms with a wealth of rich information from which to learn, optimize and grow. It is now widely acknowledged that autonomous vehicles offer the application that AI has been waiting for, and that the introduction of autonomous vehicles will be sooner than we think.

Wireless technologies and the associated benefits that they bring are an ever-increasing and indispensable part of modern society. Services such as digital radio and TV (DAB and DVB-T), GSM, 3G, 4G, Wi-Fi ,and Bluetooth are now commonplace in most executive and prestige vehicles. With demand increasing and implementation costs reducing, these technologies are becoming available across the majority of vehicles offered by manufacturers. For example, Bluetooth is common in all but the most basic entry level vehicles, and DAB and DVB-T are optional on most mid-range vehicles. Integrated GSM, 3G, 4G, 5G, and Wi-Fi technologies will be available in the next wave of models from the major high-end vehicle manufacturers, and along with intelligent transport systems (ITS), are set to deliver the much awaited ‘connected car’ and the connectivity backbone for autonomous vehicles.

For engineers though, who must look through the glossy benefits and get to the nuts and bolts of what is required to realize the change, a thorough understanding of the safety, security and functionality risks of each vehicle feature will be essential in ensuring that connected and autonomous technologies are resilient. These elements of the engineering process are inextricably linked, creating a web of intertwined and hidden risks. Security and safety systems must remain functional, whilst safety systems and functional systems must remain secure from cyber threats.

Standards form a key role in the engineering process, with ISO 26262 for functional safety and SAE J3061 for cyber security representing the state of the art for achieving high levels of system confidence. While changes are being implemented to tackle the issues surrounding connectivity and autonomy and significant work is undertaken to align the standards, even ISO 26262 Edition[2] scheduled for release in 2018 is unlikely to fully cover the requirements for autonomous vehicles. This is a reflection of the complexity of verifying the safe and secure operation of connected and autonomous vehicles rather than any inadequacy in the standards generation process.

It is the engineering processes within these standards, defining rigorous recommendations and regulations (throughout the product life-cycle from concept to decommissioning), that must be built upon to fully realize resilience for autonomous systems.

FUNCTIONAL PERFORMANCE

In order for connected and autonomous vehicles to function properly, we must ensure acceptable levels of performance for critical functions, such as braking, steering and acceleration. Key to this is the connected technology backbone; the broadcast systems and wireless links that enable connected vehicles to ‘talk’ to each other and to surrounding infrastructure. Data transmitted and received by vehicles will rise significantly, with vehicles using GSM, 3G, 4G, Wi-Fi, Bluetooth, vehicle-to-vehicle /infrastructure communication, and other data links and broadcast technologies.

Vehicle connectivity is improving, but not quickly enough for customers. According to J.D. Power’s 2016 Vehicle Dependability Study, the number of problems with infotainment, navigation, and in-vehicle communication systems—collectively known as audio, communication, entertainment, and navigation or ACEN—has increased and now accounts for 20% of all customer-reported problems[3].

For vehicle manufacturers, this poses a big issue as many customers will rate the quality of the entire electrical system in their vehicles based on the reception and connectivity experience that the vehicle delivers. Currently for mainstream vehicles, radio reception is the key tell-tale, but for high-end vehicles, this will extend to TV reception and interference. However, in the future customers will be armed with an increased number of diagnostic tools including data link corruption or dropouts, which will exhibit themselves as dropped phone calls, poor Wi-Fi reception or slow data rates. These will all form the tell-tale signs of electromagnetic interference issues or poor system/antenna performance. The irony is that the number of noise sources fitted to vehicles, and their proximity to sensitive antenna systems due to space constraints, are both causing an increased risk of electromagnetic issues and at the same time the means by which customers can perceive issues.

The risk of poor performance can lead to impact on the customer, such as the inability to make a phone call via the infotainment system, as well as warranty issues which lead to lengthy debates between customer, OEM and dealership. However issues will also reduce the effectiveness of vehicle features reliant on connectivity, some of which will be part of the vehicle control strategy. OEMs are acutely aware of these issues but are reliant on costly and time consuming subjective surveys to progress design development and gather data on connectivity performance issues meaning that signing off performance confidently is a challenge.

OEMs therefore require quantitative targets and meaningful performance measures for vehicle development. To meet these requirements for robust and accurate reception and connectivity assessment methods, a number of factors must be considered including; antenna performance, the level of wanted signal received by the vehicle when moving and the unwanted interference levels from the vehicle. All of these factors must be combined such that they reflect 'real-world performance', accurately simulating the vehicle occupant's experience to ensure that reception issues are identified and rated.

Connectivity is a key enabler in the future of mobility, and performance is crucial to feature functionality. Bottlenecks in connectivity must be avoided and data throughput must be maximized.

There are also many challenges ahead for electromagnetic testing of autonomous features, most of which surround the issue of system complexity. As functions are combined for co-pilot or auto-pilot features, system complexity grows rapidly. This in turn means that each system function is linked to multiple inputs from other vehicle systems. With this web of interconnectivity comes fragility, meaning fault modes are more likely. As such, test complexity increases due to the increase in stimuli for operational test modes. Efficient electromagnetic testing of autonomous features involves immersive situational testing, delivering services that use more diagnostic information, real-time vehicle data analysis, moving targets, and a number of other actuator and simulator systems.

SAFETY

Traditionally, safety has been considered to include active safety, such as anti-lock braking systems, blind spot information systems, and lane departure warning systems, as well as passive safety, including seat belts and airbags. However, with connectivity, electrification, and automation, safety has to be considered in a completely new light. First and foremost, new technologies mean engineers are having to get to grips with new systems and tools, which come with their own safety considerations. Secondly, new hazards are being created as a result of these new technologies. This includes exposure to electromagnetic energy and hazardous levels of electrical energy, potentially causing health-related issues, as well as thermal runaway, leading to thermal events, such as the release of chemicals.

System failures are another potential cause of hazards and can be caused by random hardware faults or systematic faults such as software defects. Widespread application of electronic systems in vehicles means it is especially important that safety risks are managed throughout product development. The ever increasing complexity of vehicle technology requires a coordinated approach to safety and functionality, and that the safety of security systems and the security of safety systems must be considered together. Only by undertaking coordinated, pragmatic and ‘goal-based’ programs can robust engineering solutions be delivered while avoiding unnecessary development rework, verification, and validation activities.

SECURITY

Increasing autonomy and connectivity has exposed us to the potential of greater levels of malicious activity in the form of cyberattacks. There are many potential threats that we face, including traditional vehicle theft, owners enhancing the performance of their own car, identity theft, or unauthorized remote access to vehicle functions. Each of these threats can have a variety of different consequences, including the financial, privacy, and operational impacts typically associated with the information security domain, as well as potential impacts upon safety and functionality.

In order to address these threats, we must use a risk-driven security engineering approach, through which appropriate security measures can be specified, designed, and implemented. Effective verification and validation is required to evaluate whether the actual level of security is as designed, and whether it is effective at preventing the relevant attacks. This involves various review, analysis, and testing activities which take several forms, including verification of correct functional behavior, proper implementation of security mechanisms, vulnerability analysis, and penetration testing to confirm the effectiveness of those mechanisms.

Due to the diverse nature of the automotive supply chain, it is essential to perform this verification for individual hardware and software components, complete embedded systems and at vehicle level, to ensure that all elements are properly integrated.

It is clear that there are still challenges on the horizon yet to be fully addressed, but with a coordinated approach to safety, security, and functionality, we will be able to better map, manage, and mitigate the risks for connected and autonomous vehicles.

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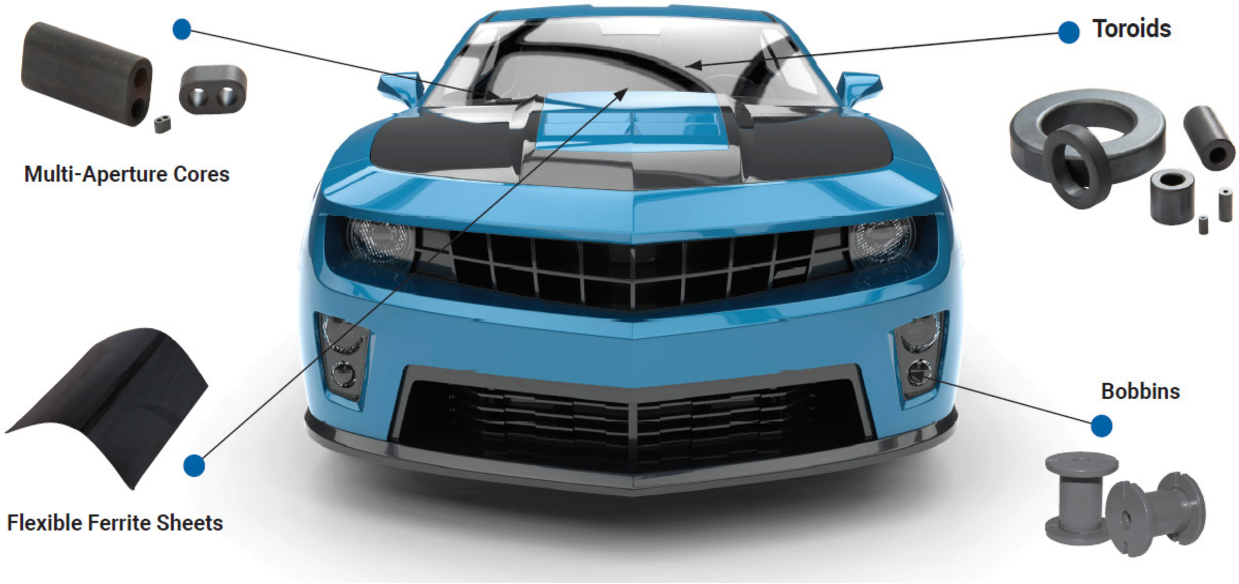

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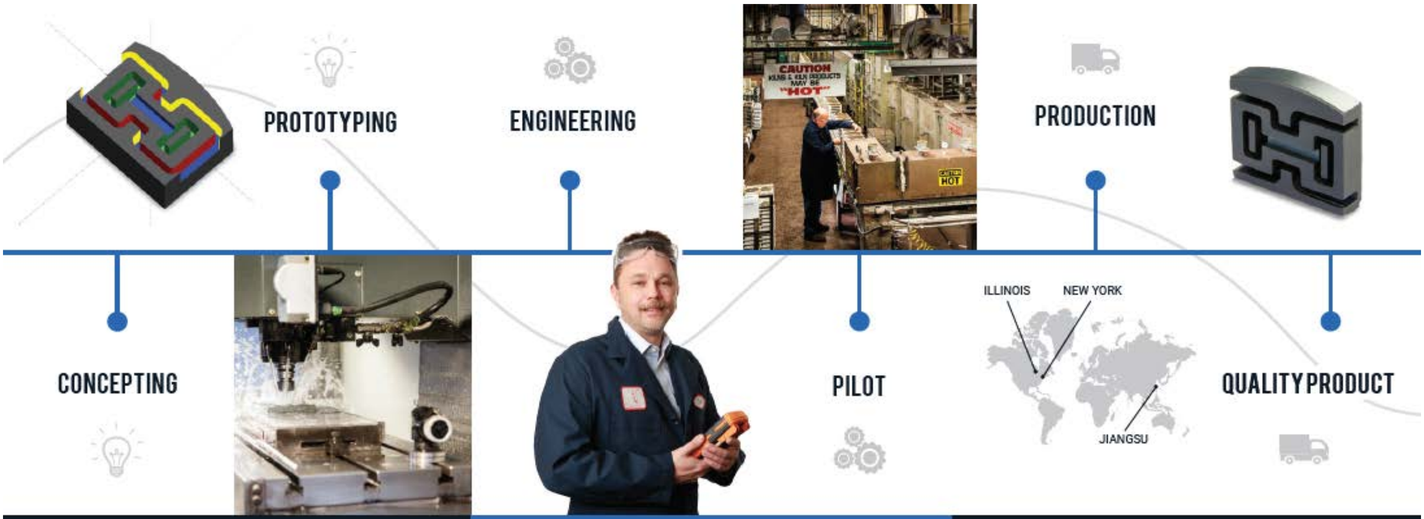

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http://www.autoalliance.org

Automotive Industry Action Group
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European Automobile Manufacturers Association
http://www.acea.be

National Automobile Dealers Association
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Automotive Council UK
http://www.automotivecouncil.co.uk

Eclipse Automotive Working group
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Automotive Industries Association of Canada
https://www.aiacanada.com

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German Association of the Automotive Industry
https://www.vda.de/en

Motor Trades Association of Australia
http://www.mtaa.com.au

MAGAZINES

Vehicular Technology Magazine, IEEE
IEEE Vehicular Technology Magazine publishes peer-reviewed articles covering advances in areas of interest to the IEEE Vehicular Technology Society: The theoretical, experimental, application and operational aspects of electrical and electronic engineering relevant to motor vehicles and associated land transportation infrastructure.

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AUTOMOTIVE EMC CONFERENCES

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AUTOMOTIVE ELECTRONICS CONFERENCES

Automotive Test Expo
October 22–24, 2019
Novi, MI, USA
http://www.testing-expo.com/usa/
This conference includes the very latest technologies and services that are designed to ensure that the highest standards are met in terms of product quality, reliability, durability and safety.

Applied Power Electronics (APEC)
March 15–19, 2020
New Orleans, LA, USA
http://www.apec-conf.org
APEC focuses on the practical and applied aspects of the power electronics business. This is not just a designer's conference; APEC has something of interest for anyone involved in power electronics:

- Equipment OEMs that use power supplies and dc-dc converters in their equipment
- Designers of power supplies, dc-dc converters, motor drives, uninterruptable power supplies, inverters and any other power electronic circuits, equipment and systems
- Compliance engineers testing and qualifying power electronics equipment or equipment that uses power electronics

Vehicle Technology Conference (VTC)
May 25–28, 2020
Antwerp, Belgium
https://events.vtsociety.org/vtc2020-spring/#
IEEE VTC will bring together individuals from academia, industry and government to discuss and exchange ideas in the fields of mobile, wireless and vehicular technology as well as the applications and services associated with such technology. Features include world-class plenary speakers, panel sessions, tutorials, and both technical and application-based sessions.

Automotive Test Expo 2020
June 16–18, 2020
Halls 8 +10, Messe Stuttgart, Germany
https://www.testing-expo.com/europe/en/
The world's largest full vehicle and component testing and validation technologies and services show.

Global Automotive Components and Suppliers
June 16–18, 2020
Hall C2, Messe Stuttgart, Germany
www.globalautomotivecomponentsandsuppliersexpo.com/en/
Automotive Component Manufacturers from around the world will be at the expo to display their very latest technologies and products, plus numerous more exhibitors will be on hand to discuss how they can participate in cost reduction within supply chains, and how they can offer new, alternative, cost-effective manufacturing and supply solutions.

24th International Automobil-Elektronik Kongress
June 23 and 24, 2020
Ludwigsburg, Germany
https://www.automobil-elektronik-kongress.de/en/registration/#registrati
The International Congress on Advances in Automotive Electronics once again proved to be a magnet with considerable influence on decision-makers in electrical/electronic system development for the vehicle industry.

Electric & Hybrid Vehicle Technology Show
September 15–17, 2020
Novi, MI, USA
http://www.evtechexpo.com
Electric & Hybrid Vehicle Technology Expo is the premier showcase for electric and hybrid vehicle technology and innovation. The show highlights advances right across the powertrain and across a wide range of vehicles from passenger and commercial to off-highway industrial vehicles.

The Battery Show - North America
September 15–17, 2020
Novi, MI, USA
https://www.thebatteryshow.com
The Battery Show is the premier showcase of the latest advanced battery technology.

AUTOMOTIVE EMC CONFERENCES (CONTINUED)

SAE CONFERENCES

SAE Hybrid and Electric Vehicle Technologies Symposium
January 28–30, 2020
Pasadena, CA, USA
https://www.sae.org/attend/hybrid
The SAE Hybrid & Electric Vehicle Technologies Symposium is the source for current and forward-looking hybrid and electric vehicle technology advances, providing industry developments from prominent representatives of OEM and supplier companies.

SAE On-Board Diagnostics Symposium - Europe
March 24–26, 2020
Dublin, Ireland
https://www.sae.org/attend
Join us in Dublin, Ireland for two and a half days of expert-led discussions—which will highlight emission regulations, emerging technologies, industry drivers, legislative policies, and standards, as they relate to on-board monitoring and calibration systems. As an attendee of OBD – Europe, you'll take part in peer discussions, learning, and networking

OTHER CONFERENCES THAT INCLUDE AUTOMOTIVE EMC

International Exhibition with Workshops on Electromagnetic Compatibility EMC (EMV 2019)
March 17–19, 2020
Cologne, Germany
https://emv.mesago.com/events/en.html
EMV is Europe's leading event on electromagnetic compatibility. Meet the industry's leading companies for EMC-equipment, components and EMC-services. The event offers a wide range of EMC-specific topics. The perfect platform to get the latest information on newest trends and developments!

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