Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Revision of Part 15 of the Commission's	)	ET Docket No. 13-49
Rules to Permit Unlicensed National	)	
Information Infrastructure (U-NII)	)	
Devices in the 5 GHz Band	)	

To: The Commission

REPLY TO OPPOSITIONS TO PETITION FOR PARTIAL RECONSIDERATION

Pursuant to Section 1.429 of the Commission's Rules, the Association of Global Automakers ("Global Automakers") hereby files its Reply to Oppositions to its Petition for Partial Reconsideration of the Federal Communication Commission's decision to expand the U-NII-3 band to 5.85 GHz in the above-captioned proceeding.[1, 2]

I. REPLY SUMMARY

Global Automakers submits that the FCC should thoroughly examine the potential for newly-authorized, unlicensed "U-NII" devices to interfere with the life-saving systems being developed by Global Automakers and its automobile industry members, the U.S. Department of Transportation

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[1] In the Matter of Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band, *First Report and Order*, ET Docket No. 13-49 (April 1, 2014) ("*First R&O*").

[2] The FCC filed public notice of the Petitions for Reconsideration in this proceeding in the Federal Register on July 30, 2014. 79 Fed. Reg. 44150 (July 30, 2014). On August 20, 2014, Global Automakers requested an extension to September 2, 2014 of the Reply to Opposition deadline. Request of Global Automakers for Extension of Time of Association, ET Docket No. 13-49 (Aug. 20, 2014). The FCC granted this request on August 25, 2014. In the Matter of Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band, Order, ET Docket No. 13-49 (Aug. 25, 2014). Therefore, this Reply is timely filed.

("DOT"), and many others. Global Automakers and others maintain that this issue has not been adequately studied by the FCC; Oppositions to Global Automakers' Petition do not prove otherwise.

Global Automakers has retained engineers to determine the impact the FCC's recent spectrum-allocation decisions could have upon vehicular safety services. The results of that study are attached to this Reply pleading; they are sobering and should be cause for regulatory concern. With *conservative* estimates regarding real-world DSRC systems, and assuming deployment of more unlicensed U-NII devices even with the FCC's new emission mask requirements, this study shows that *as few as three outdoor U-NII devices could cause serious, harmful interference to nearby DSRC operations, effectively disabling a car's DSRC-based safety systems*.[3]

Global Automakers requests that the FCC at least postpone its proposed changes that will significantly increase potential harmful interference in the 5.8-5.9 GHz spectrum until such time as the FCC has tested to ensure that U-NII interference will not rise to harmful levels. Moreover, the FCC should not proceed with potentially adverse changes to the 5.8-5.9 GHz spectrum until such time as the National Highway Traffic Safety Administration ("NHTSA") is able to fully analyze this issue as it prepares for its own complementary rulemaking proceeding with respect to radio-based public safety systems for automobiles.

The FCC's rule changes have the potential to cause harmful interference to previously licensed and authorized ITS/DSRC operations in the 5.8-5.9 GHz band. In stark contrast to all of these public safety concerns, the Oppositions fail to explain how unproven "consumer demand" for one more small slice of unlicensed commercial U-NII spectrum should, as a matter of

[3] Mehdi Alasti & Mehran Nazari, *The Potential Interference Between Newly Proposed U NII3 Band & the Currently Assigned DSRC Band*, White Paper, AdGen Telecom Group, Inc., 3 (Aug. 27, 2014) ("*Interference Analysis*"), submitted herewith as Attachment 1, at 13–18. Attachment 1 is submitted as factual support pursuant to Section 1.48(a) of the Commission's rules regarding the length of pleadings. To the extent necessary, Global Automakers requests a waiver of Section 1.429(g) of the Commission's rules so that Attachment 1 may be considered in addition to Global Automakers' Reply to Oppositions to Petition for Reconsideration.

regulatory policy, outweigh the public safety interests of millions of drivers whose lives and property may be put at risk due to adjacent channel commercial operations. For these and other reasons stated in Global Automakers' Petition and this Reply, Global Automakers requests that the FCC favor public safety over the inchoate demands of U-NII equipment vendors, and heed NHTSA's request that the interference issue be tested and resolved before allowing untold numbers of U-NII devices to create interference problems for vehicular safety services.

II. THE FCC SHOULD WAIT FOR NHTSA TO COMPLETE ITS ANALYSIS

As Global Automakers has consistently maintained, the efforts of other government agencies researching DSRC-enabled vehicular safety technologies ought to be taken into account before any substantial and potentially adverse changes are made regarding licensed and unlicensed uses in the 5.8-5.9 GHz band.[4] Underscoring these concerns, on August 20, 2014, NHTSA published its Advanced Notice of Proposed Rulemaking ("ANPRM") on vehicle-to-vehicle ("V2V") and vehicle-to-infrastructure ("V2I") technology,[5] accompanied by a comprehensive research report on V2V.[6] The ANPRM and report are the result of several years of relevant research and study by that agency.[7]

NHTSA's ANPRM explicitly requests "research to support" the contention that unlicensed devices will not interfere with DSRC functions.[8] In its report, NHTSA states that "[f]urther research to move toward deployment [of DSRC technologies] has been identified (and detailed in this report) and will be conducted to address the following: . . . The impact of spectrum sharing

[4] *See* Global Petition for Partial Reconsideration, ET Docket No. 13-49, 9 (May 1, 2014); Reply Comments of the Alliance of Automobile Manufacturers, Inc. and the Association of Global Automakers, Inc., ET Docket No. 13-49, iv, 7, 10 (July 24, 2013); Comments of the Alliance of Automobile Manufacturers, Inc. and the Association of Global Automakers, Inc., ET Docket No. 13-49, 7–8 (May 28, 2013).

[5] 79 Fed. Reg. 49270 (Aug. 20, 2014) [hereinafter "V2V ANPRM"].

[6] NHTSA, Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application xiv (Aug. 2014) [hereinafter "NHTSA V2V Report"].

[7] *Id.* at xiv.

[8] V2V ANPRM at 49272, ¶ 18.

with U-NII devices . . . ."[9] NHTSA understands that what is at stake here is far more important than the prospective commercial interests of U-NII device and chipset manufacturers. According to NHTSA's V2V report, just two of many possible V2V applications (Intersection Movement Assist and Left Turn Assist) could prevent up to 592,000 crashes, 270,000 injuries, and 1083 vehicular deaths every year.[10] NHTSA's ANPRM represents great progress in the development of ITS: "V2V technology represents that next great advance in saving lives."[11] NHTSA's ANPRM specifically addresses the question of potential interference from unlicensed devices.

Given NHTSA's stated desire to have these interference issues studied and resolved *before* unlicensed commercial devices can create havoc to vehicular safety systems, it behooves the FCC to reconsider its recent regulatory actions. The Executive Branch itself has consistently emphasized the importance of regulatory consistency and coordination between agencies: "Each agency shall avoid regulations that are inconsistent, incompatible, or duplicative with its other regulations or those of other Federal agencies."[12] Federal agencies promulgating rules are at a minimum expected to avoid conflicts with other agencies' regulations or rulemaking processes.[13] "In developing regulatory actions and identifying appropriate approaches, each agency shall attempt to promote . . . coordination, simplification, and harmonization."[14]

Now, before it is too late, Global Automakers requests that the FCC pause to coordinate its 5.8-5.9 GHz spectrum decisions with the public safety efforts that are currently underway at

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[9] NHTSA V2V Report, at xix.

[10] NHTSA V2V Report at xvi.

[11] *Id.* (statement of U.S. Transportation Secretary Anthony Foxx).

[12] Regulatory Planning and Review, Exec. Order No. 12866, 58 Fed. Reg. 51735 (Sept. 30, 1993).

[13] *Cf.* Improving Regulation and Regulatory Review, Exec. Order No. 1356376, 76 Fed. Reg. 3821 (Jan. 18, 2011) ("Some sectors and industries face a significant number of regulatory requirements, some of which may be redundant, inconsistent, or overlapping. Greater coordination across agencies could reduce these requirements, thus reducing costs and simplifying and harmonizing rules.").

[14] *Id.*

NHTSA. The wide-scale deployment of tens of thousands of new, commercially-sold U-NII devices in the 5.8-5.9 GHz band could not possibly be consistent with NHTSA's public safety regulatory efforts.

Like NHTSA, Global Automakers asks only that the FCC engage in appropriate testing and study to determine whether deployment of additional U-NII devices in the 5.8-5.9 GHz band, even with the additional "emission masks" proposed by the FCC, could cause potentially fatal interference to vehicular safety systems. The minimal delay that this testing might cause to plans for further use of this radio spectrum should be weighed carefully against the potential for lethal consequences if newly-authorized U-NII devices interfere with public safety and automakers ability to comply with NHTSA's proposed crash avoidance standards set forth in the ANPRM. This delay is surely minor when measured against the value of the lives at risk should a wireless traffic safety system fail to function at a critical moment due to interference from unlicensed U-NII devices.

II. PRIORITY IN THE 5.8-5.9 GHZ SPECTRUM SHOULD BE GIVEN TO INCUMBENT PUBLIC SAFETY USERS

The Oppositions to Global Automakers' Petition downplay the intended public safety uses of the DSRC-allocated spectrum. Instead, several filers stress the need to appease "consumer demand" for increased amounts of data over U-NII networks.[15] It bears noting that the FCC's record in this rulemaking proceeding on the "demand" side consists largely of the views of U-NII chipset manufacturers, commercial broadband service operators, and their trade associations, as opposed to the views of consumers themselves. Unlike other, recent FCC rulemaking proceedings

[15] *See, e.g.,*Opposition of the National Cable and Telecommunications Association, ET Docket No. 13-49, 1 (Aug. 14, 2014) ["NCTA Opposition"]; *see also* Opposition of the Information Technology Industry Council, ET Docket No. 13-49, 2 (Aug. 14, 2014) ["ITI Opposition"] (American consumers are using, and demanding increasingly robust amounts of data over wireless networks . . . .").

that have generated high volumes of comments from interested consumers, this regulatory proceeding, at least according to Appendix B of the *First R&O*, generated fewer than ten.[16]

Despite lack of record evidence to support the "demand" premise put forth by commercial vendors, the FCC has a Congressional mandate to fulfill with respect to the 5 GHz band.[17] And, as a general concept "free" spectrum for Internet-access services is of course beneficial at least to those consumers who actually need more U-NII spectrum. Still, the FCC's central task as guardian of the Nation's radio spectrum is to engage in a rational weighing of competing interests *before* reaching any regulatory conclusions as to who should have the right to use that spectrum. *See, e.g., FCC v. Nat'l Citizens Comm. for Broad.*, 436 U.S. 775, 804, 810 (1981). Here, it is by no means obvious that the FCC has appropriately balanced or even considered the likely harm to vehicular safety systems on the one side against the financial interests of commercial enterprises that have clamored for more 5 GHz radio spectrum. In the view of NHTSA, Global Automakers and many others, commercial demand for more "free" spectrum simply does not warrant putting long-term, multi-stakeholder public safety research and development at risk.

For instance, NHTSA has emphasized the importance of V2V to facilitate the development and introduction of new advanced safety applications as well as to enhance existing crash avoidance technologies. Despite increases in vehicles' structural safety, "a significant number of annual crashes [resulting in 32,479 fatalities in 2011[18]] remains that could potentially be addressed through expanded use of more advanced crash avoidance technologies."[19]

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[16] *First R&O* app. B, at 43.

[17] *See* Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. 112-96 §§ 6001–6703, 126 Stat. 156 (the "Spectrum Act").

[18] National Highway Traffic Safety Administration, Fatality Analysis Report System (FARS), Final 2011 Data, www.nhtsa.gov/FARS (last accessed Feb. 12, 2014).

[19] NHTSA V2V Report at xiii.

Interference on the frequencies used by V2V systems would pose unacceptable risks to the operation of this public safety technology. NHTSA states that:

> Given that Wi-Fi use is growing exponentially, "opening" the 5.8-5.9 GHz part of the spectrum could result in many more devices transmitting and receiving information on the same or similar frequencies, which could potentially interfere with V2V communications in ways harmful to its safety intent. ***More research needs to be done on whether these Wi-Fi enabled devices can share the spectrum successfully with V2V, and if so, how.***[20]

Balanced against these public safety concerns, the FCC ought to consider how relatively little spectrum has been set aside for critical ITS/DSRC services compared to the large amount of licensed and unlicensed radio spectrum available for commercial broadband use. The ITS allocation constitutes a very small portion of radio spectrum in relation to the spectrum available for commercial and wireless broadband use.

The Wireless Internet Service Provider's Association ("WISPA") compares spending on consumer products with spending on public safety.[21] But, that is precisely the type of inappropriate balancing of interests that the FCC is expected to eschew when allocating spectrum in the public's best interests. No revenues from the sale of additional U-NII devices would warrant interfering with life-saving services.

Moreover, accident and injury avoidance is monetarily valuable in its own right. Morgan Stanley has estimated the *annual* savings attributable to avoiding 90% of traffic accidents caused by human error at $563 billion.[22] All that is required for the FCC to fulfill its statutory mandate

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[20] *Id.* at xvii (emphasis added).

[21] Opposition of the Wireless Internet Service Providers Association, ET Docket No. 13-49, 4 (Aug. 14, 2014) ["WISPA Opposition"]. Similarly, the Fixed Wireless Communications Coalition ("FWCC") argues that Global's Petition will "impair[] a widely deployed and useful service [unlicensed U-NII devices] in favor of a more recent newcomer whose actual deployment remains uncertain." Opposition of the Fixed Wireless Communications Coalition, ET Docket No. 13-49, 6 (Aug. 14, 2014) ["FWCC Opposition"].

[22] Adam Jones, et al., *Tesla Motors Inc., Nikola's Revenge: TSLA's New Path of Disruption*, Morgan Stanley Research N. Am. 26 (Feb. 25, 2014).

is to engage in appropriate testing to ensure that these public safety interests are not put at risk by the desire of commercial interests to sell more U-NII devices.

III. THE *FIRST R&O* WILL GREATLY INCREASE THE USE OF U-NII DEVICES, WHICH WILL CAUSE INTERFERENCE PROBLEMS FOR ITS

As several filers point out, interference has been a looming issue in the development of ITS.[23] Stating that there is a problem is by no means the same as taking actions to guard against that problem. For its part, Global Automakers has retained consulting engineers to begin analyzing what impact the FCC's recent spectrum-allocation decisions might have upon vehicular safety services.

The results of that study are attached to this Reply pleading; they are sobering and should be cause for regulatory concern. With *conservative* estimates regarding a real-world DSRC system, and assuming deployment of more unlicensed U-NII devices in the 5.8-5.9 GHz band even with the FCC's new emission mask requirements, this study shows that ***as few as three outdoor U-NII devices could cause serious, harmful interference to nearby DSRC operations, effectively disabling a car's DSRC-based safety systems***.[24]

As the *Interference Analysis* explains, the FCC provided only a 5 MHz guard band between DSRC-enabled devices and U-NII devices.[25] U-NII devices are unlicensed, available through commercial sale, and can be sold in massive volumes for which the FCC has no regulatory control; hence, "it is not possible to ascertain how many U-NII devices might congregate in a given geographic area."[26] The FCC has not yet addressed serious questions regarding the aggregate effect of out-of-bands emissions that may arise when a number of U-NII devices operate

[23] *See, e.g.*, Opposition of the Wi-Fi Alliance, ET Docket No. 13-49, 4 (Aug. 14, 2014); FWCC Opposition at 8.
[24] *Interference Analysis*, at 13–18.
[25] *Id.* at 3, 6.
[26] *Id.* at 3.

simultaneously in a small geographic area.[27] Concentrated U-NII devices can impede and degrade messages transmitted on adjacent networks—when operating at the high speeds necessary to protect drivers from vehicular accidents, the impediment posed by U-NII devices is a serious threat.[28] "Ignoring important arguments and evidence" such as those presented by Global Automakers, the *Interference Analysis*, and the NHTSA ANPRM, would likely be arbitrary and capricious. *See David Ortiz Radio Corp. v. FCC*, 941 F.2d 1253, 1260 (D.C. Cir. 1991).

For reasons explained in the *Interference Analysis*, from an engineering and consumer operations perspective it is imperative for the reliability of DSRC technologies that interference levels created by other RF emitting sources on and around the DSRC spectrum be maintained at low and safe levels. High interference and low signal-to-noise-interference-ratio ("SINR") may cause safety messages to be dropped, and emergency alerts to fail, in the DSRC network which could reduce the effectiveness of DSRC in preventing crashes, injuries, and saving lives. All of these operational concerns will be exacerbated once thousands of unlicensed U-NII devices are deployed in and around DSRC-outfitted cars and networks.[29]

The time to study this serious issue and to conduct appropriate testing and measurements is now—*before* a large scale deployment of U-NII devices operating immediately adjacent to the DSRC-allocated band can cause fatal problems.[30] The inchoate interests of commercial vendors can surely wait until these public safety issues are fully and fairly answered.

CONCLUSION

Accordingly, Global Automakers requests that the FCC partially reconsider its *First R&O* as set forth herein and in Global Automakers' Petition. It is respectfully requested that the FCC

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[27] *See id.*

[28] *See id.*

[29] *Id.*

[30] *Id.* at 4.

engage in additional analysis to ensure that expanded, unlicensed use of the 5.8-5.9 GHz band will not interfere with the band allocated by the Commission for the development of DSRC "safety-of-life" systems.

Respectfully submitted,

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CERTIFICATE OF SERVICE

I hereby certify that on this 2nd day of September, 2014, a true and correct copy of the foregoing Reply to Oppositions to Petition for Reconsideration In the Matter of Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Infrastructure (U-NII) Devices in the 5 GHz Band, ET Docket No. 13-49, was served by electronic mail* on the following:

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September 2, 2014

ATTACHMENT 1

The Potential Interference Between Newly Proposed U-NII3 Band & the Currently Assigned DSRC Band

White Paper

Prepared By: AdGen Telecom Group, Inc.

September 2, 2014

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Abstract

This White Paper considers the need for further study of the potential for harmful radiofrequency interference between existing traffic safety applications using dedicated short-range communications (DSRC) services and the expanded band for Unlicensed National Information Infrastructure (U-NII) services as proposed in Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band, *First Report and Order*, 29 FCC Rcd. 4127 (2014) (*First Report & Order*) [5].

Traffic safety applications using DSRC technologies and applications within Intelligent Transport Systems (ITS) are becoming an important paradigm as they enable enhanced safety features for the vehicles to prevent crashes, save lives, avoid injuries and reduce property damages. Many of these applications require real-time communication with high reliability. The Federal Communications Commission (FCC) allocated 75 MHz of spectrum in the 5.9 GHz band (5850 – 5925 MHz) for use by DSRC vehicle safety and mobility applications.

The FCC allocated the U-NII radio band as part of the radio frequency spectrum used by unlicensed intentional radiators. The FCC issued a Notice of Proposed Rule Making to allow U-NII devices to operate up to 5850 MHz [16]. This White Paper elaborates on the issue that the out of band emission of the unlicensed intentional radiators (e.g., WiFi devices) operating on the U-NII band may cause serious reliability issues for DSRC applications. The National Highway Traffic Safety Administration (NHTSA) has also raised concerns [6] about this interference issue. We strongly recommend more investigations and comprehensive testing to ensure that there will be no adverse impact on the performance of the DSRC technologies before any large scale commercial deployment of the U-NII devices based on the FCC's *First Report & Order*.

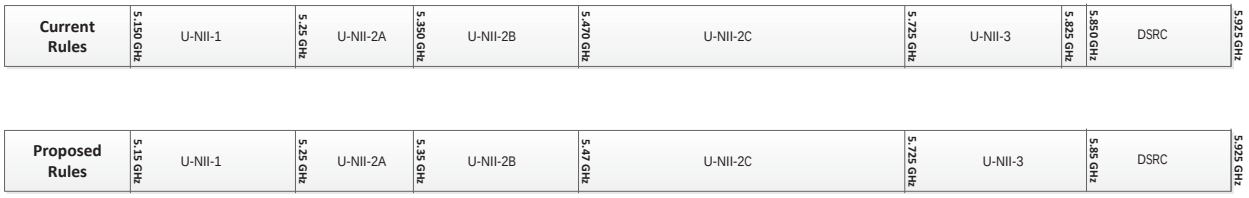

Figure 1: FCC's current allocation and FCC's new proposed rules

Executive Summary

As the Federal Communications Commission (FCC) allocates spectrum to various services, it must ensure that each service may operate effectively within its allocation, free from out-of-band emissions or other interference from allocations in nearby spectrum. The existing traffic safety allocations may be threatened by the Commission's recent U-NII allocations in adjacent spectrum. More study is necessary to determine whether U-NII may interfere with traffic safety operations.

In 1999, the FCC allocated 75 MHz of 5.9 GHz spectrum (5850 – 5925 MHz) for intelligent transportation systems (ITS) [14]. Dedicated short-range communications (DSRC), short range wireless communication channels designed for vehicle safety purposes in wireless access in vehicular environment (WAVE) networks, sprung up as a result of the allocation. WAVE is intended to reduce injuries, deaths, and economic losses from vehicle collisions by transmitting basic safety messages between vehicles to facilitate warnings to drivers concerning impending crashes. WAVE messages may lead to a DSRC system warning a driver of impending danger so that the driver can take corrective action. WAVE messages may become a necessary foundational technology for potential vehicle automation features in the future.

Vehicular accidents often occur when a vehicle strays from its normal operation. Drivers must respond quickly. If radio-based public safety equipment inside a vehicle is to respond accurately to provide an effective warning to the driver, it must respond quickly. To be effective, WAVE networks must deliver safety messages reliably between the vehicles with very low latency for crash avoidance. Radio interference of any kind will slow, impair, and in some instances permanently disrupt these critical messages.

The Unlicensed National Information Infrastructure (U-NII) radio band is part of the radio frequency spectrum used by IEEE 802.11a devices [3]. The U-NII devices are unlicensed intentional radiators that operate in the frequency bands 5.150 – 5.350 GHz and 5.470 –- 5.825 GHz, using wideband digital modulation techniques to provide high data rate mobile and fixed communications for individuals, businesses, and institutions [4]. In 2013, the FCC issued a Notice of Proposed Rule Making with the intent of extending the upper edge of the 5.725 –

5.825 GHz band to 5.850 GHz [16]. The Commission subsequently adopted the proposed rule in its *First Report & Order* on April 1, 2014 [5].

U-NII spectrum abuts traffic safety spectrum. The DSRC community had developed a band plan that included a 5 MHz guard band at 5.850 – 5.855 GHz. This band plan was subsequently included in a 2003 FCC Report and Order (FCC 03-324) [15]. This 5 MHz guard band is the only spectral separation between WAVE devices and U-NII unlicensed intentional radiators.

Because U-NII devices are unlicensed and for sale commercially, it is not possible to ascertain how many U-NII devices might congregate in a given geographic area. When a number of U-NII devices operate simultaneously in a small geographic area, a serious question as to the aggregate effect of the out-of-band emissions is raised.

According to the *First Report & Order*, the FCC apparently conducted no interference studies (either in a lab setting or real-world setting) to ascertain whether a 5 MHz buffer would be sufficient to protect traffic safety operations from the aggregate out-of-band emissions from the unlicensed use specified in the U-NII proceeding.

Traffic safety applications are understandably subject to strict engineering standards. IEEE802.11p, IEEE1609.x, and SAE J2735 specify a set of standards for WAVE networks to allow the auto industry to develop safety equipment for vehicles [1]. These standards are intended for safety message exchange between high speed vehicles and between the vehicles and the roadside infrastructure in robust, highly reliable, fast, and high throughput WAVE networks in order to deliver the safety messages on time for crash avoidance. Interference caused by a high concentration of simultaneously operating U-NII devices in a small geographic area may increase latency and impair the messages transmitted on DSRC. Consequently, as a matter of sound RF engineering principles, out-of-band emissions from U-NII devices should be limited so that WAVE network requirements may operate according to their standards of robustness, high reliability, low latency and high throughput.

This White Paper articulates the need for field measurements and comprehensive test plans to investigate the potential adverse impact of aggregation of U-NII devices authorized under the

First Report & Order on the performance of WAVE networks. It is highly recommended that these tests and studies be conducted *before* any large scale deployment of unlicensed intentional radiators operating in the U-NII band will be allowed to take place.

I. An Overview of DSRC Technology

Government, industry and universities have made enormous investments in traffic safety technologies under the big umbrella of *intelligent transportation systems* (ITS) over a period of many years. ITS investments led to the development of safety and traffic management technologies in vehicles and road infrastructure. W*ireless access in vehicular environments* (WAVE) technology operating on the *dedicated short-range communications* (DSRC) bands are one of the key enabling technologies for the emerging ITS services.

The primary goal of Travel Safety Standards is to develop scalable, robust, extremely low latency and high throughput networks for road safety messaging and control that will significantly reduce collisions, save lives and reduce property loss. WAVE messages enable vehicles to perceive some threats sooner than is possible by the human eye, cameras or radar.

Some studies estimate that enabling only two of the safety messaging applications (i.e., Intersection Movement Assist (IMA) and Left Turn Assist (LTA)) could annually prevent from 25,000 to 592,000 crashes, save from 49 to 1,083 lives, avoid 11,000 to 270,000 injuries, and eliminate 31,000 to 728,000 accident events involving property damage [6]. The number of lives potentially saved would likely increase significantly with the implementation of all the safety applications that would be enabled if all vehicles were equipped with DSRC capability [6].

In addition to the benefits from collision avoidance, WAVE networks may be used for other community purposes such as traffic management, environment monitoring, congestion management, emission reduction, toll collection, smart parking, emergency services and a wide range of other location-based services [2]. On a consumer level, WAVE networks are available to assist drivers with their travel plans – avoiding traffic snarls, enabling smarter parking strategies, and allowing quicker access to emergency services.

In order for DSRC to provide reliable, high-speed vehicle-based communication for crash prevention safety applications, a number of requirements have to be satisfied:

- Fast Network Acquisition: Safety applications require the immediate establishment of communications and frequent updates.
- Very Low Latency: The safety messages have to be delivered in milliseconds.
- High Reliability: Safety applications must work in high vehicle speed mobility conditions and deliver performance immune to extreme conditions.
- Standard Based Solutions: Ensuring interoperability, which is the key to successful deployment of safety applications, using widely accepted standards.
- Security: Providing safety message authentication and privacy.

In WAVE networks, the wireless devices are either an on-board unit (OBU) or a roadside unit (RSU). WAVE enables two classes of communications: vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I). The direct V2V communication allows low latency messaging between an OBU in a vehicle with the other OBUs within its radio coverage area; this is an essential requirement for safety applications such as collision warning [2]. WAVE messages could include vehicle speed, heading, brake status, and other information [6]. V2I communications allow the wireless exchange of critical safety and operational data between vehicles and highway infrastructure. V2I exchanges are intended primarily to avoid or mitigate motor vehicle crashes but they also enable a wide range of other safety, mobility, and environmental benefits.

Because of the nature of their operation, WAVE networks require a limited interference RF environment. Particularly, V2V communications must manage the relative velocity between two vehicles moving in the opposite direction; this is the sum of their individual speeds which could be much higher than the velocities encountered in the other wireless technologies. Therefore, V2V communication may deal with much faster fading and much more Doppler frequency spread than any other wireless systems [2][7]. Clearly, such V2V messaging in a WAVE network may have a very tight latency requirement; any network decisions based on delayed information could be quite harmful.

V2V messaging also has to be robust in suddenly extremely abnormal circumstances under which collisions are more likely to happen. Robust V2V messaging is required even in harsh environments where there are many vehicles in the geographic radio coverage area.

To meet these challenges, a WAVE network has to support robustness and reliability, security, low-latency and high throughput [7].

II. DSRC Regulatory Requirements

In a 1999 Report and Order (FCC 99-305), the FCC allocated 75 MHz licensed spectrum in the 5.9 GHz frequency band to DSRC applications [14]. In a 2003 Report and Order (FCC 03-324), the lowest 5 MHz out of the 75 MHz spectrum was reserved as the guard band following seven 10-MHz channels [15]. See Table 1 [8].

Channel No.		Frequency Range (MHz)	Channel Use	Notes
170		5850 - 5855	Reserved	Guard Band
172		5855 - 5865	Service Channel	Special FCC designation for V2V safety and other safety
174	175	5865 - 5875	Service Channel	
176		5875 - 5885	Service Channel	
178		5885 - 5895	Control Channel	
180	181	5895 - 5905	Service Channel	
182		5905 - 5915	Service Channel	
184		5915 - 5925	Service Channel	Special FCC designation for longer distance public safety

Table 1: FCC Allocation of DSRC Spectrum

As shown in Table 1, the spectrum constitutes one control channel (CCH) and six service channels (SCHs) [8]. The CCH carries high-priority short control messages or management data, while other data are transmitted on the SCHs. The pair of channels (channel 174 and 176, and channel 180 and 182) can be combined to form a single 20-MHz channel, channel 175 and 181, respectively. Note that only a five MHz guard band (Channel 170) separates the spectrum allocated to the V2V communication (Channel 172) and the band below Channel 170 (U-NII band).

III. Performance Requirements for DSRC Technology

In order to verify whether the aggregate out of band interference created by the U-NII unlicensed intentional radiators could be harmful to the operation of the DSRC devices, the performance of the WAVE network has to be evaluated under the presence of some measure of adjacent channel interference.

It is important to understand that the set of performance requirements for DSRC devices and safety applications are still under development by NHTSA. Nevertheless, the required latency and capacity required by the existing Travel Safety Standards could be used to evaluate the reliability, security, speed of transmission/impact on latency, and scalability of the traffic safety applications in the U-NII environment.

In order to meet the requirements of the Traffic Safety Standards, the IEEE 1609 family, IEEE802.11p and the Society of Automotive Engineers (SAE) J2735, all form the key components of the proposed WAVE protocol stack. See Figure 2 [2][10].

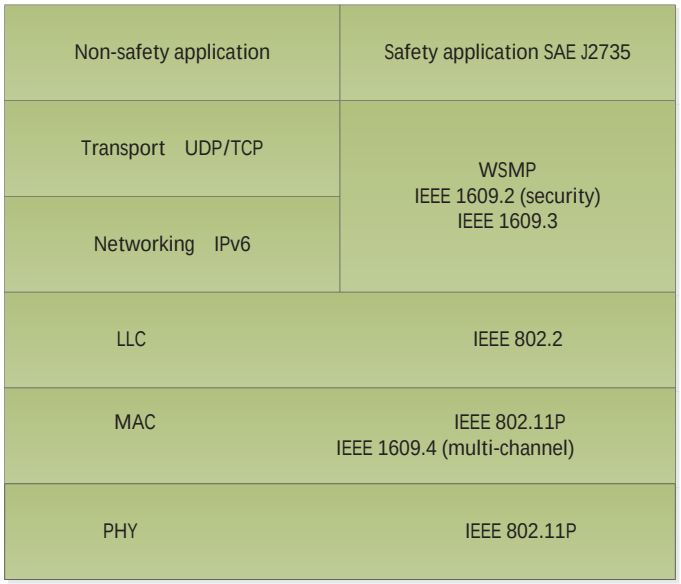

Figure 2: The WAVE protocol stack

IEEE802.11p is an amendment to IEEE802.11-2007 for WAVE. 10-MHz channels in the 5.9 GHz frequency band was in the IEEE802.11 in 2007 standard and the DSRC community adopted it as an industry decision, while the Wi-Fi industry normally implements the OFDM PHY on the 20-MHz channels. The 10 MHz OFDM channel option of IEEE802.11p supports the data rates of 3, 4.5, 6, 9, 12, 18, 24, and 27 MHz [2][10]. V2V applications need bit rates of up to 6 Mbps [7]. The transmitter power of DSRC devices falls into four classes between 0 dBm to 28.8 dBm [2]. The typical coverage of a radio link is between 10 meters to 1 Km depending on the channel environment, the transmit power and the utilized modulation and coding [2].

Because of the strict operational demands that WAVE networks must meet, such as much higher delay spread and much higher fast fading which results in lower signal level and higher inter-carrier interference (ICI), the DSRC receiver is more sensitive to harmful radio interference than other wireless networks. As a result, the IEEE802.11p standard requires the signal energy to decay faster as a function of frequency to further reduce the intra-band adjacent channel interference for the required robustness.

There have been a number of safety applications proposed and studied in many projects. The capacity of the DSRC system has to be large enough to accommodate a 10 Hz Basic Safety Message (BSM) transmission by all vehicles within a communication range. Additionally, low

latency requirements of all safety applications are such that DSRC communications can support a vehicle's BSM updates to surrounding vehicles.

One latency requirement for DSRC is that each vehicle must have a chance to send its status every 100 ms [2]. For example, consider a scenario where two vehicles are converging at a relative speed of 180 km/h on a two way-street toward each other (each car is driving 55 miles/hour) in two adjacent lanes and one of them suddenly loses vehicular control. Within 100 ms, their distance can be shortened by 5 m; if the two vehicles are close to each other quick, evasive action has to be taken. In practice, the total latency is the total time taken for sensing the event, communicating the event to the drivers and taking reactive action by the drivers. Therefore, it is vital to meet the tight latency requirements for the V2V messaging. Any packet loss due to low signal to interference noise ratio (SINR) and high bit error rate (BER) would require waiting for the subsequent BSM to be sent, resulting in higher total latency for warnings and a potential collision, essentially defeating or undermining the onboard safety systems in both of the vehicles. In other words, any undesired interference on the V2V communication Channel 172 (5855 – 5865 MHz) may significantly and adversely impact the performance of the V2V messaging.

The packet loss rate directly depends on the SINR at the receiver which is a combination of the transmitter OBU power, path-loss, fast fading effect, background noise and the interference created by the out of band sources. (The in-band interference issue for the DSRC technology is nicely managed by the IEEE802.11P MAC/PHY standard.). Due to fast relative speeds in V2V communication, fast fading has a big negative impact on the SINR at the receiver OBU. Studies show that that in order to successfully decode a 6 Mbps DSRC packet an SINR of approximately 7 dB is required [7]. In order to avoid collisions in abnormal situations, the interference on V2V communication Channel 172 has to be maintained at a level low enough for reliable V2V communications.

IV. Proposal for Unlicensed National Information Infrastructure (U-NII) Band

The FCC allocated the Unlicensed National Information Infrastructure (U-NII) radio band as part of the radio frequency spectrum used by IEEE-802.11a devices [3][4]. In 2013, the FCC issued a Notice of Proposed Rule Making [16] in an effort to increase the utility of the 5 GHz band where fixed and mobile broadband U-NII devices are permitted to operate by allowing U-NII devices to operate in the 5.150-5.350 GHz and 5.470-5.850 GHz bands [5][16]. U-NII devices are unlicensed intentional radiators, which use wideband digital communications techniques to provide high bit rate mobile and fixed communications used by individuals, businesses, and institutions, particularly for wireless local area networking (WiFi). A summary of the FCC's rule changes are as follows [5]:

- For U-NII devices in the 5.150-5.250 GHz band, the FCC removed the indoor-only restriction and increased the permitted power, thus increasing the commercial utility of this portion of the radio spectrum and accommodating the next generation of Wi-Fi technology.
- The FCC extended the upper edge of the 5.7250-5.8250 GHz band to 5.850 GHz and consolidated the Part 15 rules applicable to all digitally modulated devices operating across this 125 megahertz of spectrum to ensure that all such devices comply with U-NII requirements intended to protect authorized users from harmful interference.
- The FCC required that all U-NII device software be secured to prevent its modification to ensure that the devices will operate as authorized by the Commission, thus reducing the potential for harmful interference to authorized users.
- To protect Terminal Doppler Weather Radar (TDWR) systems and other radar systems operating in the 5.250-5.350 GHz and 5.470-5.725 GHz bands from harmful interference, the FCC modified certain technical rules and compliance measurement procedures for U-NII devices operating in these bands.

Based on FCC's *First Report & Order* [5], U-NII devices can now radiate power up to 5850 MHz with a guard band separation of 5 MHz with the Channel 172 (5855 – 5865 MHz) V2V communication channel. Given the tight latency requirements of the V2V communication channel, it is imperative for all U-NII devices operating on or near 5850 MHz to create very low out of band power on V2V communications Channel 172. This will be explained later in this White Paper.

V. The Out of Band Emission of U-NII Devices on DSRC Band

Because U-NII devices are unlicensed, there will be an indeterminable number of such devices operating in any given geographic radio coverage area where there may be one or many vehicles with On-Board Units (OBUs). One or more U-NII devices in a geographic radio coverage area, acting individually or in aggregate, may create interference through out-of-band emissions that is harmful for the V2V communication Channel 172. Even if the U-NII emissions are masked, in accordance with IEEE 802.11ac, out-of-band emissions may cause harmful interference to vehicle safety operations.

The FCC's *First Report & Order* [5] specifies the out of band emission limit of the U-NII-3 devices. Based on Paragraph 90 of the FCC's *First Report & Order*, the out of band emission of U-NII devices must be "below -17 dBm/MHz within 10 MHz of band edge, and below -27 dBm/MHz beyond 10 MHz of the band edge" [5]. In other words, the out of band emission from the U-NII-3 band into V2V communication channel 172 based on the new rules would be: ~ 100 microWatt over 5.855 – 5.860 GHz and ~ 10 mircoWatt over 5.860 – 5.865 GHz. Therefore, the total out of band emission of a U-NII device over the V2V communication channel 172 can be as high as ~ 110 microWatt (~ -9.6 dBm) in total. This value is considered as the out of band emission of a U-NII device into the V2V communication channel 172 later in analysis in this White Paper.

When a number of these U-NII devices operate at 5 GHz and in the radio coverage area of an OBU (a likely scenario given that these are unlicensed devices that will be sold by a variety of commercial enterprises), the aggregate interference created by these U-NII devices could be quite harmful for the V2V communication Channel 172.

VI. Interference Issues of U-NII Band on the Performance of DSRC Technology

The out-of-band emissions created by the unknown number of unlicensed intentional radiators operating within the U-NII band could cause harmful interference with the V2V communications Channel 172 because there is only one 5 MHz guard band separating the U-NII band from V2V communication Channel 172 band. This section explains why harmful interference could well occur to DSRC operations absent changes to the FCC's expanded authorization for U-NII devices.

The requirement for V2V safety has limited the maximum BSM power to 20.0 dBm. The reason for limited power is to achieve the effective transmission range of up to several hundred meters that is required for most of the envisioned V2V safety applications, without interfering with DSRC receivers at longer distances where the information is less useful.

The received power at another OBU is attenuated depending on the distance between the two vehicles. Free space path-loss as well as high fast fading margin will further attenuate the received signal level. Typically, the received signal level is between -90 to -95 dBm. Moreover, the noise floor for a typical DSRC system with bandwidth of 10 MHz is -99 dBm (-107 dBm thermal noise at 5.9 GHz, 5 dB hardware noise, and a tolerance of 3 dB) [5] , which is below the typical received signal level. However, the reliability and robustness of V2V communications with this low signal strength may be seriously, adversely impacted by any out of band interference created by U-NII devices operating on the adjacent channels.

With only 5 MHz separation between the V2V communications Channel 172 and the unlimited U-NII operations, and for reasons explained in the previous example, it is possible that interference to traffic safety operations will result on a regular basis. Based on the out of band emission limit for U-NII devices (based on Paragraph 90 of the FCC's *First Report & Order* [5]) a 5 MHz guard band may not be sufficient to avoid interference and to guarantee the required reliability and robustness of the V2V communication on Channel 172. The higher the concentration of simultaneously operating U-NII devices in a given geographic radio coverage area of any given OBU at any given time will result in more aggregate interference created by

the U-NII devices, seriously impairing the performance of V2V communications. In light of these conclusions, comprehensive testing and field measurements should be performed to investigate whether the out of band interference created by these unlicensed intentional radiators will be routinely harmful for DSRC technology. Testing and measurement would also be critical to determine whether the U-NII out of band emission limit will be adequate to protect operational DSRC systems from harmful interference caused by widespread deployment of U-NII band devices.

VII. Adverse Impact of U-NII Devices Operating in U-NII Band on DSRC Technology

This section presents examples of two V2V use cases in which U-NII devices operating in the U-NII band may cause harmful interference to the operation of V2V communications on Channel 172. Note that these examples do not intend to prove that the operation of unlicensed intentional radiators operating in the U-NII band will negatively impact all traffic safety operations. Rather, the examples demonstrate two likely scenarios in real-world situations, to explain that further investigation, comprehensive field measurements and test plans should be required on this interference issue before additional large scale deployment of unlicensed intentional radiators operating should be allowed in the U-NII band.

Example 1 - Intersection Collision Warning: Consider two vehicles approaching an intersection as shown in Figure 3, with speeds of 40 miles per hour, 60 meters from the intersection. As shown in Figure 3, there are a number of buildings in the radio coverage area of the OBUs. Because of these buildings, there is no line of sight between the two vehicles. Also, let us assume that there are U-NII devices in and around these buildings all operating in the U-NII band.

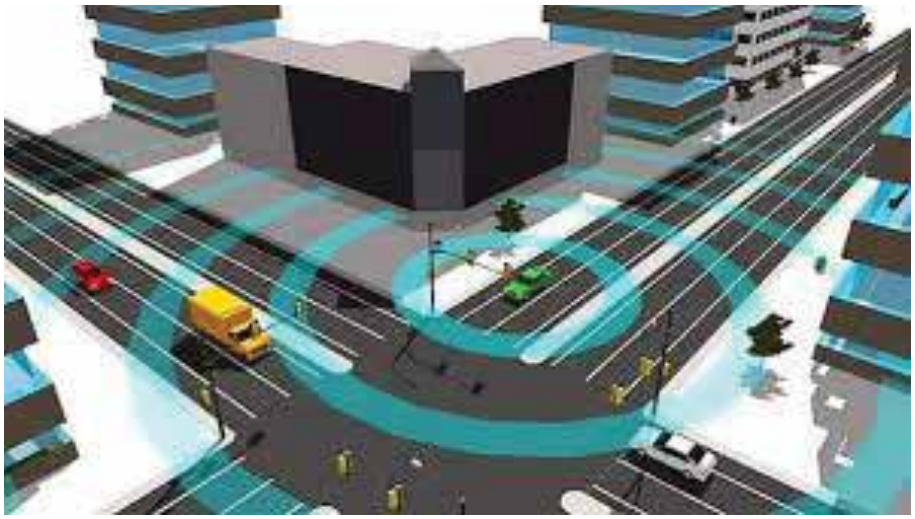

Figure 3: Example 1, where U-NII devices on the U-NII band may interfere with V2V communication

Based on the previous discussions, we consider the OBU transmit power (Tx) to be 20.0 dBm. Due to the reflection around the corners, the free space distance between the two OBUs is roughly 120 meters. Due to the reflections around the corner, the free space path-loss (PL) for 120 meters[1] distance at frequency 5855 MHz would be -89.4 dB [12]. We assume that the shadow fading (SF) in urban areas is -8 dB, and the fast fading (FF) for this scenario is -10 dB. The total loss for the OBU signal would be the summation of the free space path-loss, shadow fading, and fast fading, which is -107.4 dB. Consequently, the received OBU power (Rx) is -87.4 dBm. For a QPSK with ½ rate coding, a 7 dB SINR is required for reliable messaging between the OBUs on the V2V communication. Therefore, the allowable total interference and noise power (Clear Channel Assessment - CCA threshold) would be -94.4 dBm.

The floor noise is assumed to be -99 dBm, which is much lower than the allowable total interference and noise power (CCA threshold). Let us assume that there are a number of U-NII devices in and around those buildings operating on the U-NII band with out of band emission of -9.6 dBm over the band of 5855 - 5865 MHz. Let us also assume the average distance between these U-NII devices and the receiver OBU is 40 meters.

[1] For more accurate and reliable path loss analysis a deterministic method such as "ray tracing", which is based on the physical laws of wave propagation must be used. Ray tracing method produces more accurate and reliable predictions of the path loss than the empirical methods; especially for short distances. However, ray tracing method is time consuming and requires detailed and accurate description of all objects in the propagation space, such as buildings, roofs, windows, doors, and walls.

The critical question in this hypothetical is: "*How many of these U-NII devices would it take to create a negative impact (harmful interference) on the performance of the DSRC devices and interfere with the V2V messaging in this example?*" The answer is: not many at all.

The free space path-loss between the outdoor U-NII devices and the OBU device for 40 meters distance is -79.8 dB. Also, the (urban) shadow fading from the U-NII device to the OBU is also -8 dB. The total loss from the U-NII device to the OBU would be -87.8 dB. Consequently, the out of band interference created by the U-NII device on the OBU device would be -97.4 dBm. In other words, as few as two U-NII outdoor devices operating on the U-NII band could cause harmful interference problems for the V2V messaging between the two OBUs. Note also that the OOBE from even one U-NII transmitter operating inside one of the vehicles would interfere with the V2V messaging to that vehicle's OBU. This scenario is summarized in Table 2:

OBU transmit power (Tx)	**20.0 dBm**
Path-loss for 120 meters (PL)	**-89.4 dB**
Shadow Fading (SF)	**-8 dB**
Fast Fading (FF)	**-10 dB**
Total loss	**-107.4 dB**
OBU received power (Rx)	**-87.4 dBm**
Required SINR	**7 dB**
Total interference + noise power (CCA Threshold)	**-94.4 dBm**
U-NII out of band emission at 5855 MHz	**-9.6 dBm**
Path-loss from U-NII to OBU for 40 meters	**-79.8 dB**
Shadow fading	**-8 dB**
Total loss from U-NII device to OBU for 40 meters	**-87.8 dB**
U-NII out of band emission at OBU	**-97.4 dBm**
Out of band emission of two U-NII devices at OBU	**-94.4 dBm ≥ -94.4 dBm**

Table 2: Summary of Example 1

Example2 - Emergency Vehicle Warning:

One of the use cases of V2V communications is emergency vehicle warning, where an on-board device alerts drivers to vehicles braking ahead, even around corners and through traffic. With this use case scenario, electronic brake systems transmit a wireless signal to illuminate a dashboard on the vehicles. This scenario is depicted below in Figure 4.

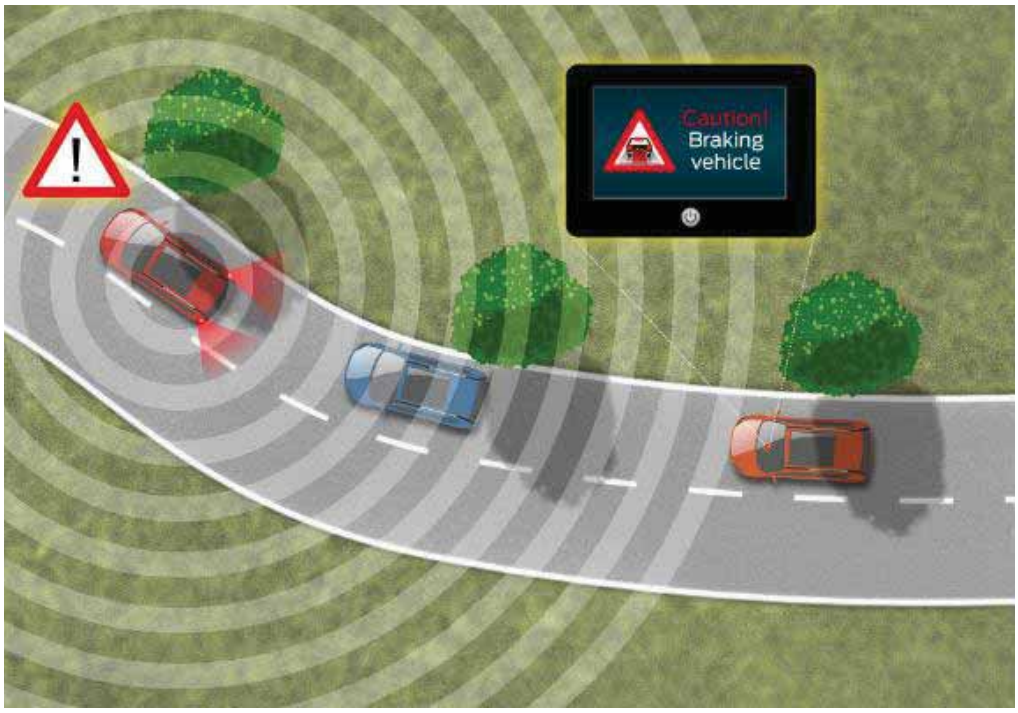

Figure 4: Example 2, where U-NNI devices may interfere with V2V communication emergency vehicle warning.

Consider a scenario where a vehicle is followed by other vehicles driving on a highway in a suburban area with speeds of 50 miles per hour, and the first vehicle is forced to come to an abrupt stop for whatever reasons. See Figure 4. Let us also assume that the distance between the first vehicle and the vehicle following it is 200 meters. Also, let us assume that a number of outdoor U-NII devices are within the close proximity of the vehicle and are operating in the U-NII band.

Again, we assume the OBU transmit power to be 20.0 dBm, the free space distance between the two OBUs is 200 meters, and so the path-loss for 200 meters distance is -93.8 dB [12]. Let us assume that the (suburban) shadow fading on this highway is -5 dB, and the fast fading is -9.0 dB, so that the total loss for the OBU signal would be -107.8dB. The received OBU power is -87.8 dBm. For a 7 dB SINR for the reliable messaging between the safety equipment on the V2V communication, the allowable total interference and noise power would be -94.8 dBm.

Again, we assume that the out of band emission of the U-NII devices over the band of 5855 - 5865 MHz is -9.6 dBm. Let us assume the average distance between these U-NII devices and the receiver OBU is 40 meters. The path-loss between the U-NII device and the OBU device for 40 meters distance is -79.8 dB, and shadow fading is -5 dB. Consequently, the total loss from the outdoor U-NII devices and the OBU device is -84.8 dB. Therefore, the out of band interference created by the U-NII device on the OBU device is -94.4 dBm. In other words, even one U-NII outdoor device operating on the U-NII band could cause harmful interference problems for the V2V messaging thereby interfering with this emergency vehicle warning system. This scenario is summarized in Table 3:

OBU transmit power (Tx)	**20.0 dBm**
Path-loss for 200 meters (PL)	**-93.8 dB**
Shadow Fading (SF)	**-5 dB**
Fast Fading (FF)	**-9.0 dB**
Total loss	**-107.8 dB**
OBU received power (Rx)	**-87.8 dBm**
Required SINR	**7 dB**
Total interference + noise power (CCA threshold)	**-94.8 dBm**
U-NII out of band emission at 5855 MHz	**-9.6 dBm**
Path-loss from U-NII to OBU for 40 meters	**-79.8 dB**
Shadow fading	**-5 dB**
Total loss from U-NII device to OBU	**-84.8 dB**
U-NII out of band emission at OBU	**-94.4 dBm**
Out of band emission of one U-NII device at OBU	**-94.4 dBm > -94.8 dBm**

Table 3: Summary of Example 2

Example 1 and Example 2 are real-world scenarios that are likely to occur once DSRC systems are deployed on our Nation's roadways. These examples strongly suggest that further investigation is required to make sure that the out of band emissions of the U-NII devices on the U-NII based as authorized under the FCC's new proposal, will not be harmful to DSRC technology.

VIII. Conclusions

The new DSRC technologies and applications for enhancing traffic safety can potentially decrease the number of vehicle accidents on the roads, save lives, avoid injuries and reduce

property damages. DSRC technologies depend on delivery of safety messages between vehicles on time. Reliability and fast packet delivery are important features for DSRC.

For reasons explained in this White Paper, from an engineering and consumer operations perspective it is imperative for the reliability of DSRC applications that interference levels created by other RF emitting sources on and around the DSRC spectrum be maintained at low and safe levels. High interference and low signal-to-noise-interference-ratio (SINR) may cause safety messages to be dropped, and emergency alerts to fail, in the DSRC network which may lead to accidents that could have been prevented and the associated human and economic consequences of those accidents.

Recently, the FCC adopted its *First Report & Order* for the U-NII band which extends the upper edge of the 5.725 - 5.825 GHz band to 5.850 GHz for additional commercial uses. This proposal leaves only a 5 MHz guard band separation between the DSRC devices and the unlicensed intentional radiators operating on the U-NII band. This White Paper has explained how the FCC's proposal may lead to unlicensed intentional radiators operating on the U-NII band at undesired levels of out of band interference on the DSRC band, which in turn will cause the loss of safety messages and interfere with emergency systems in the DSRC network.

The National Highway Traffic Safety Administration (NHTSA) has expressed its concerns about this potential safety issue [6]. This White Paper demonstrates the clear need for field measurements and comprehensive test plans in order to investigate the potential impacts of the FCC's proposal on the performance of DSRC applications before any large scale deployment of unlicensed intentional radiators operating in the U-NII band should be allowed to proceed.

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Authors Biographies

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Mehdi Alasti received his PhD in the area of Wireless Communication Networks from University of Maryland at College Park in Jan 2001, with the focus on MAC Layer & Application Layer cross layer design for Integrated Voice & Data Wireless Networks. Afterwards, Dr. Alasti was one of the founders of Zagros Networks Inc, a fables semiconductor start-up company headquartered in Rockville, MD (2001 - 2003), where he worked as a Principle Engineer reporting to the VP of Engineering. From July 2003 - December 2003 Dr. Alasti joined the Electrical & Computer Engineering Department of University of Maryland as a Faculty Research Associate. From January 2004 – December 2006, Dr. Alasti joined Advanced Technology Group of Airvana Inc (www.airvana.com Chelmsford, MA) reporting to Airvana CTO and working on the next generation wireless technologies and next generation products for Airvana Inc. Dr. Alasti joined AdGen Telecom Group in 2007 and is working as a Technology Strategist consultant focusing in 4G (WiMAX) and Core Network, LTE RAN, EPC Core (security & authentication, QoS, CSFB, SRVCC, VoLTE, E911, roaming/IPX, data offloading), IMS, LTE RAN, cloud based OSS/BSS, and municipal WiFi network. Dr. Alasti has published a number of technical papers in IEEE and holds a number of patents.

Mehran Nazari

Mehran Nazari has more than 30 years of experience in the design, audit, build and operation of numerous telecommunications networks in both developed and emerging markets. He has worked with varying technologies from GSM, CDMA, UMTS and LTE to WiFi/WiMax - as a result, he has been involved in strategic planning and implementation of many different generations of telecommunications technologies and infrastructure vendors. In addition to defining technology roadmaps for start-up operations, he has assisted incumbent operators review and refine existing product and service portfolios and well as enabling platform landscapes. He has extensive background and expertise in network topology, signaling and interconnect plans between fixed networks in domestic US and intentional markets. Mr. Nazari was appointed to the Communications Security, Reliability, and Interoperability Council (CSRIC IV) in May 2013

and also is a Board member of the NG9-1-1 Institute. Mr. Nazari received his Bachelor of Science degree from George Washington University in electrical engineering, and is pursuing a master's degree in telecommunications and computer science.