The FAA's Center of Excellence for UAS Research
ASSURE
Alliance for System Safety of UAS through Research Excellence

MISSISSIPPI STATE UNIVERSITY

RASPET FLIGHT RESEARCH LABORATORY

# A40 – Validation of ASTM Remote Identification Standards Literature Review

03 December 2021

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ADS-B | Automatic Dependent Surveillance-Broadcast |
| ASTM | American Society for Testing and Materials |
| BT4 | Bluetooth 4 |
| BT5 | Bluetooth 5 |
| BVLOS | Beyond Visual Line of Sight |
| DAC | Drone Advisory Committee |
| DAA | Detect and Avoid |
| EU | European Union |
| FAA | Federal Aviation Administration |
| FAR | Federal Aviation Regulation |
| FRIA | FAA Recognized Identification Area |
| GCS | Ground Control Station |
| GNSS | Global Navigation Satellite System |
| LE | Low Energy |
| NAN | Neighbor Awareness Network |
| NAS | National Airspace System |
| NPRM | Notice for Proposed Rulemaking |
| RID | Remote Identification |
| RF | Radio Frequency |
| SWIM | System Wide Information Management |
| UA | Unmanned Aircraft |
| UAS | Unmanned Aircraft System |
| UASSRF | Unmanned Aircraft Systems Safety Research Facility |
| UTM | UAS Traffic Management |

| **Revision number** | **Edition date** | **Reason for change** | **Pages/Sections Affected** |
|---|---|---|---|
| Initial Draft | 12/03/2021 | Initial Draft | All |
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# 1 INTRODUCTION

The use of unmanned systems has grown dramatically over recent years leading to an influx of recreational and commercial drones in to the low-altitude airspace. The safety and security of the National Airspace System (NAS)are paramount to the Federal Aviation Administration (FAA) as they aim to continue the integration of unmanned aircraft systems (UAS) into airspace system. Remote Identification (RID) of UAS has been implemented in support of this integration effort to increase safety and security by having UAS self-disclose pertinent information on their operations.

# 2 PURPOSE

This document serves as a literature review for current and future researchers on documentation relating to RID of UAS. The intent is to inform the research team at the Unmanned Aircraft Systems Safety Research Facility (UASSRF) of RID standards and its functionality. It also serves as a brief introduction to wireless communications and, more specifically, how they relate to RID. The wireless network protocols that are used for RID are discussed in an aim to inform specifically about the methods through which RID will send its messages. This literature review will aid in informing the public of the core concepts of RID as well as the core concepts explored in this research.

# 3 BACKGROUND

RID refers to the ability of an in-flight UAS to be capable of broadcasting specific identification and location information that can be received by other parties. The information consists of items such as position, altitude, and serial number that is associated with the FAA registration process. The RID information provides law enforcement and other public safety stakeholders with critical information on UAS operations to reduce the risk of them interfering with other aircraft in flight, as well as people and property on the ground to ensure safety and security. RID is essentially a "digital license plate" for UAS that allows them to be easily identified and tracked for security purposes. Prior to the RID rule, the process for UAS registration and identification had challenges with the aircraft's small size and the lack of an on-board operator (Federal Aviation Administration, 2021). Through the implementation of this rule, the process by which UAS are identified provides the FAA and law enforcement with greater efficiency in oversight of compliance with the regulations.

## 3.1 History

Full integration of UAS into the airspace has been an incremental process that the FAA continues to work towards. On December 16, 2015, a rule was published that required unmanned aircraft (UA) to be registered and display a registration number on the aircraft. A rule established in 2016 imposed limitations on UAS operations such as nighttime operations, limitations on twilight operations, and restrictions on operating over people. On December 31, 2019, the Remote Identification of Unmanned Aircraft Systems Notice for Proposed Rulemaking (NPRM) was published. This NPRM would eventually lead to the RID rule as it stands today, partially due to public feedback.

> *"The FAA received approximately 53,000 comments on the NPRM. A significant amount of the comments were submitted by individuals, many of whom identified*

> *as recreational flyers. In addition, the FAA received numerous comments from UAS manufacturers, other aviation manufacturers, organizations representing UAS interest groups, organizations representing various sectors of manned aviation, State and local governments, news media organizations, academia, and others."* (Federal Aviation Administration, 2021)

The final rule that resulted from the NPRM will take effect on September 16, 2023, giving UA pilots time to make sure their drones will compliant and satisfy the requirements for RID.

#### *3.1.1 Elimination of ADS-B*

A major concern of the FAA for the use of Automatic Dependent Surveillance-Broadcast (ADS-B) is that the large number of UAS in use could negatively impact the safe operation of manned aircraft. Essentially, the frequencies at which ADS-B operates would become saturated and could blind ground receivers (Federal Aviation Administration, 2021). A large influx of ADS-B users could also affect pilots as there would now be a much higher amount of traffic that would be present on their ADS-B displays and could negatively affect their workload. As of March 16, 2021, UAS operators are prohibited from using ADS-B out transponders. There are exceptions to this rule under certain conditions. The UAS must be operated under a flight plan and the person operating the UAS must maintain two-way communication with air traffic control. The use of ADS-B in this instance must be approved by an FAA Administrator and is not a direct replacement for RID (General Operating & Flight Rules 14 C.F.R § 91, 2022).

#### *3.1.2 Removal of Network RID Requirement*

Originally, UAS were going to have to send their messages through a network connection. This meant that a UAS would transmit all required message elements through the internet to a third-party service provider. This provider is known as an RID UAS Service Supplier (USS) and would have distributed all RID information to necessary parties. The FAA received multiple comments on the NPRM stating concern over the network requirements and the ability for pilots to satisfy the requirements for it. The primary challenge for network RID was its reliance on Wi-Fi or cellular network service being available where UAS may fly. Commenters to the NPRM also stated that they had concerns over privacy. For the time being, the FAA has removed the requirement for network based RID from their regulation, but the ASTM standard still covers the RID USS framework.

### 3.2 Regulations and Standards

The FAA is responsible for defining the rules and requirements for of RID. ASTM International is developing the standards to provide the basis upon which an RID device can be designed to meet the intent of the FAA's ruling. Summaries of the information presented in these documents is presented here.

#### *3.2.1 FAR Part 89*

Part 89 of the Federal Aviation Regulations (FAR) (Remote Identification of Unmanned Aircraft, 14 C.F.R § 89 , 2022) covers the requirements that RID equipped UAS, and modules must meet as of September 16, 2023.

Performance requirements are presented for both systems including position accuracy being within 100 feet with 95% probability for the UAS, ground control station (GCS), and take off location. The GCS altitude must be within 15 feet while the UAS and takeoff location must be within 150 feet horizontally with 95% accuracy. The time of measurement to time of broadcast must be no more than 1 second and a message must be broadcast, at a minimum, every second. Additionally, a self-test must be conducted by the RID equipment and for standard RID equipped UAS to check that it is properly functioning. If the RID equipment for a Standard RID UAS is not function during this test, then it must prohibit take-off until it works.

### *3.2.2 ASTM International Remote Identification Standard*

The ASTM standard for RID "defines message formats, transmission methods, and minimum performance standards for two forms of Remote ID: broadcast and network" (ASTM International, 2020) as well as addressing communications and test requirements for these two forms. The standard is explicitly for UAS that meet the requirements in Part 89.

> *"This specification is applicable to UAS that operate at very low level (VLL) airspace over diverse environments including but not limited to rural, urban, networked, network degraded, and network denied environments, regardless of airspace class." (ASTM International, 2020)*

In this context, VLL generally refers to below 150 m (500 ft).

## 4 REMOTE ID RULE OVERVIEW

All UAS pilots must comply with the FAA's rule on RID and register their UAS. RID systems are categorized two ways: a standard RID UAS has built-in RID equipment that is tied to an aircraft that has a registered serial number with the FAA or RID modules that can be added to a noncompliant aircraft to give it RID capabilities. If a UAS does not meet either of these criteria, then it will only be able to fly at an FAA-Recognized Identification Area (FRIA). UAS can operate in these areas without broadcasting RID, however, the UAS must remain within visual line of sight and stay within the designated area. These areas can only be requested by community-based organizations and educational institutions (Remote Identification of Unmanned Aircraft, 14 C.F.R § 89 , 2022). Figure 1 (Federal Aviation Administration, 2021) displays these three different compliance methods.


Figure 1. Three ways pilots can meet Remote ID rule.

Each system above has requirements for the minimum message elements that must be present in their RID broadcasts. Table 1 displays these requirements (Remote Identification of Unmanned Aircraft, 14 C.F.R. §§ 89.305-89.315, 2022).

Table 1. Neccessary broadcast information for RID devices.

| **Standard RID UAS** | **RID Module UAS** |
|---|---|
| Identity<br>- Serial Number<br>- Session ID | Identity<br>- Serial Number<br>- Session ID |
| UAS<br>- Latitude<br>- Longitude<br>- Geometric Altitude<br>- Velocity | UAS<br>- Latitude<br>- Longitude<br>- Altitude<br>- Velocity |
| GCS<br>- Latitude<br>- Longitude<br>- Geometric Altitude | Take off location<br>- Latitude<br>- Longitude<br>- Altitude |
| UTC Time Mark | UTC Time Mark |
| Emergency Status Indicator | |

These message elements must broadcast the entire time the UAS is powered on. The UAS must also remain in the line-of-sight of the pilot operating it. An operator of a standard RID UAS may opt to broadcast either their drone's serial number or their session ID, they are not required to do both. The data elements shown above are sent in message blocks where each block has a different type of information it is carrying. The six message types are shown below with optional messages marked by an asterisk.

Table 2. RID message types and their elements.

| *Message Type* | *Message Elements* |
|---|---|
| 0x0 | UAS ID |
| | UAS Type |
| 0x1 | Operational Status* |
| | Aircraft Latitude & Longitude |
| | Geodetic Altitude |
| | Height Above Takeoff* |
| | Pressure Altitude* |
| | Vertical Accuracy |
| | Horizontal Accuracy |

| | |
|---|---|
| | Speed Accuracy |
| | Speed |
| | Direction |
| | Vertical Speed |
| | Timestamp |
| 0x2 | Authentication Info* |
| 0x3 | Operation Description* |
| 0x4 | Operator Latitude & Longitude* |
| | Operator Altitude |
| | Group Count* |
| | Group Radius/Height* |
| 0x5 | Operator ID* |
| 0xF | Message Pack |

The elements marked with an asterisk are optional to be sent in the RID message, unless required by a local regulation.

### 4.1 Broadcast RID Performance Characteristics

Broadcast RID has distinct performance characteristics that will encourage potential users to adopt it, meet the requirements by the FAA, and adhere to the ASTM standard. These characteristics, both advantages and disadvantages are presented in the ASTM standard in appendix X1 (ASTM International, 2020). Use of a broadcast method allows UAS and operators to comply with the RID ruling without the need for any external supporting infrastructure or equipment other than an RID module (and this is only required if the UAS is not a standard RID UAS as defined by the FAA). This also enables broadcast RID to be cheaper than the method of network RID, which requires external infrastructure to operate. However, broadcast RID does present drawbacks, such as electromagnetic interference affecting the capable broadcast range. There is also an increased reliance on the sensitivity of a receiver’s antenna to be able to receive these messages.

The FAA has stated devices that fall under 47 CFR §15 (Radio Frequency Devices, 47 C.F.R Part 15, 2021) are to be used for RID purposes and that there are compromises made due to this.

> *“The FAA acknowledges that the use of part 15 devices for remote identification broadcasts may result in reduced distance and reliability as compared to solutions leveraging licensed spectrum. The FAA finds that such solutions, however, would necessitate specialized equipment to receive the broadcasts that would be incompatible with the concept of remote identification data being widely accessible to the public using existing smart devices.”* (Federal Aviation Administration, 2021).

The FAA has necessitated that all broadcasting devices be designed to maximize their range within the Part 15 confinements so that RID is provided to as many receivers as possible.

## 5 WIRELESS COMMUNICATIONS OVERVIEW

Wireless communication is made possible through use of electromagnetic waves that have been encoded with data by modulating the properties of the wave. This modulated wave can then be transmitted along a designated frequency where the wave will be received and the data on it decoded to become usable. There are a multitude of wireless services that have been developed since the inception of wireless communication with the first being broadcast radio. Broadcast service has three main properties (Molisch, 2011) that differentiates it from other wireless services:

1. The information is only sent in one direction. It is only the broadcast station that sends information to the receiver; the receiver does not transmit any information back.
2. The transmitted information is the same for all users.
3. The information is transmitted continuously.

As mentioned in the above, there are two main components required for wireless communication: a transmitter and a receiver. A transmitter is the device that generates the radio waves that carry the data. The following components are typically found in a receiver:

- **Power Supply:** Provides the necessary electrical power to operate the transmitter.
- **Oscillator:** Creates alternating current at the frequency on which the transmitter will transmit. The oscillator generates a sine wave, which is referred to as a carrier wave.
- **Modulator:** Adds useful information to the carrier wave.
- **Amplifier:** Amplifies the modulated carrier wave to increase its power. The more powerful the amplifier, the more powerful the broadcast.
- **Antenna:** Converts the amplified signal to radio waves.

Figure 2 (Lowe, n.d.) shows a breakdown of the typical components of a transmitter.

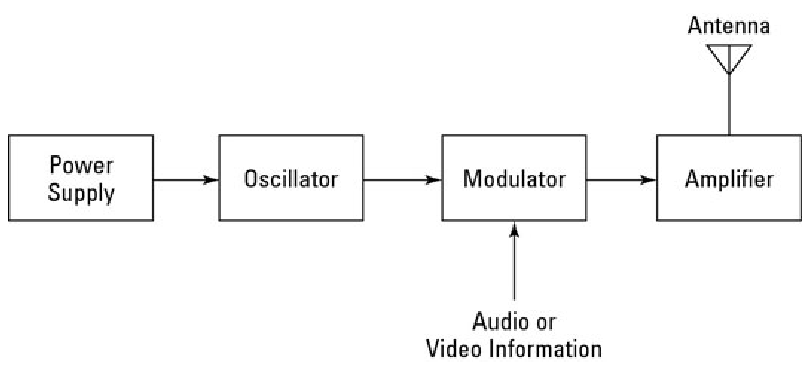


Figure 2. Typical components of a transmitter.

A receiver captures the radio waves sent by the transmitter and processes them into a useable format whether that be audio, video, or simply data. Typical components of a receiver are as follows:

- **Antenna:** Captures incoming radio waves.
- **RF Amplifier:** Amplifies the weak radio frequency (RF) signal from the antenna so that the signal can be processed.
- **Tuner:** A circuit that extracts signals of a particular frequency from a mix of signals.
- **Detector:** Separates the desired information from the carrier wave. For example, the detector in a radio would separate the audio information from the wave.

Figure 3 below shows the components that would be found in a generic receiver.

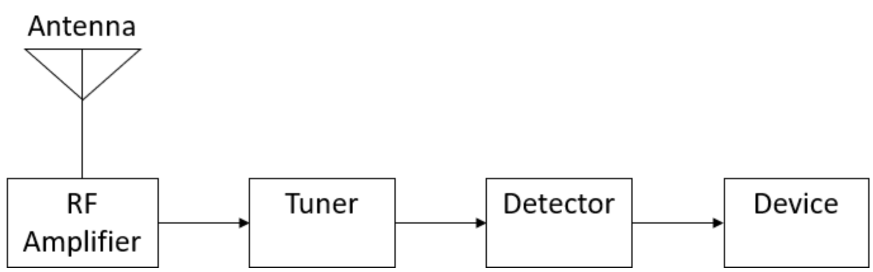


Figure 3. Typical components of a wireless receiver.

### 5.1 Antennas & Transmitters

Antennas are the backbone of any wireless system as they allow for messages to be sent and received. There are a multitude of different antenna designs that all can have different performance characteristics, but they all fall under two main types: directional and omnidirectional. Directional antennas have a focused direction that they send or receive their signal. This allows them to have a higher range typically but a much lower coverage area. Directional antennas can be categorized even further into semi-directional and highly directional. Figure 4 and figure 5 (Access Agility, 2018) show examples of what a typical beam width would look like for each of these.

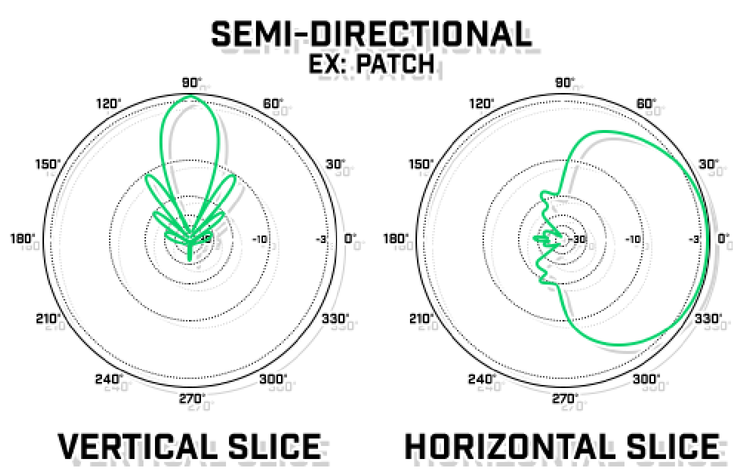


Figure 4. Beam pattern for semi-directional antenna.

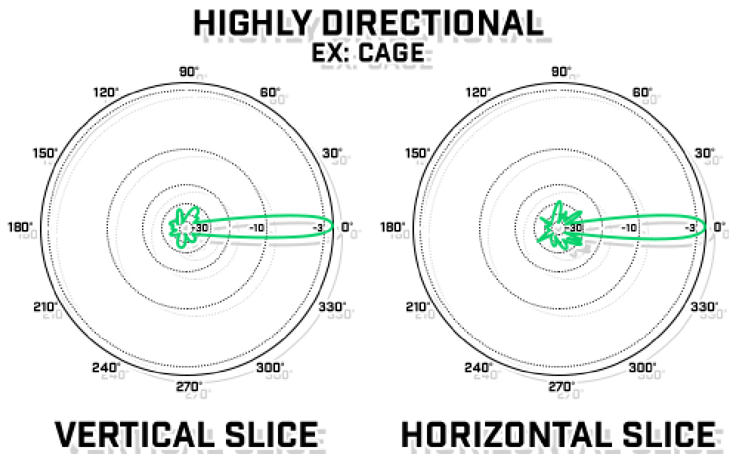


Figure 5. Beam pattern for highly directional antenna.

Both antennas have broadcast patterns that are only in specific directions, but the highly directional antenna covers a much smaller azimuth. The other antenna type, omnidirectional, is the opposite of the above and instead broadcasts in every direction as seen in figure 6.

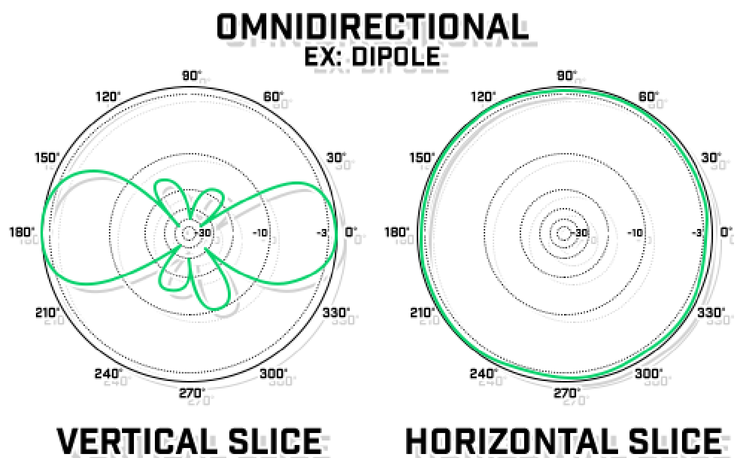


Figure 6. Beam pattern for omnidirectional antenna.

For the purposes of RID, an omnidirectional antenna would be favored as it allows for the messages to be sent in all directions around the UAS. A directional antenna would have difficulties ensuring that users can receive the messages if they are not in the correct location relative to the orientation of the antenna and its broadcast pattern.

# 6 WIRELESS NETWORK PROTOCOLS

There are four wireless network protocols that are used to send RID messages from a UAS to a receiver: Bluetooth 4, Bluetooth 5, Wi-Fi Neighbor Awareness Network (NAN), and Wi-Fi Beacon. Each of these protocols is discussed in the ASTM standard for RID except for Wi-Fi Beacon. However, the Aerospace and Defense Industries Association of Europe – Standardization (Aerospace and Defence Industries Association - Standardization , 2021) for the European Union (EU) has recognized it as a Broadcast RID method. Each of these protocols have their own distinct characteristics but were all chosen due to them being easy to implement as well as their ability to handle the traffic that RID systems will generate. These technologies are compatible with commonly carried hand-held devices that have their own receiver antenna allowing for RID to be more easily accessible. Both Bluetooth and Wi-Fi also continuously broadcast a signal and advertise their presence making them ideal for broadcast RID where a receiver does not need to directly connect to the transmitting device.

### 6.1 Bluetooth 4.0

Bluetooth 4.0 (BT4), also known as Bluetooth Low Energy (LE) is one of the more easily accessible methods of broadcast RID as the majority of potential receiver devices have implemented it (i.e., smartphones, laptops, etc.). However, most UAS do not have Bluetooth capabilities meaning that an additional module would more than likely have to be added to enable this capability on existing UAS or integrated into UAS produced in the future. BT4 operates in the frequency band of 2402 to 2480 MHz across 40 different channels. RID broadcast uses a subset of these channels: 37, 38, and 39. (Gomez, Oller, & Paradells, 2012). These channels, shown in figure 7 (Cox, 2021), are known as beacon channels and are used to broadcast to non-specific endpoints rather than directly connecting another device (ASTM International, 2020). This gives BT4 the ability to continuously broadcast a signal without a direct receiver.

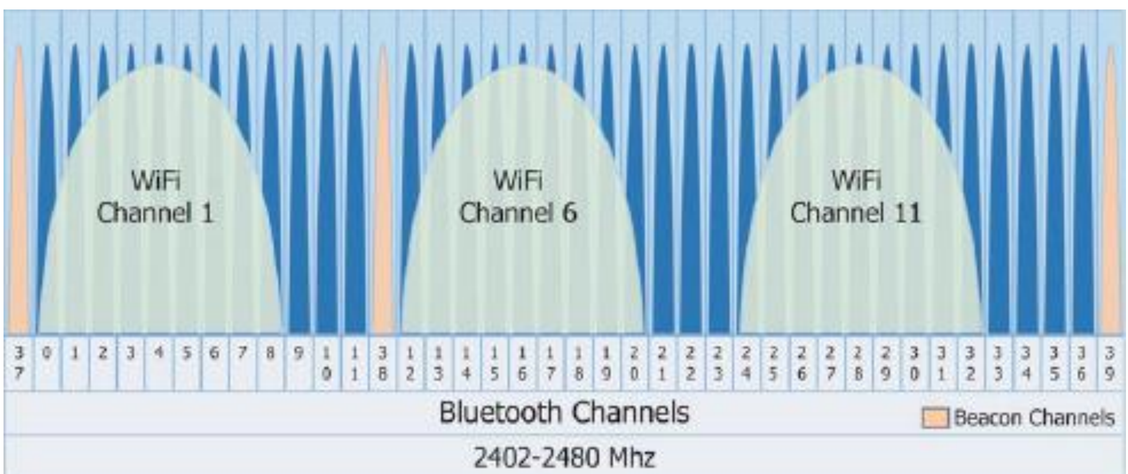


Figure 7. Bluetooth channels with highlighted beacon channels for RID.

The ASTM RID standard states that BT4 has the ability to send messages up to 400 meters in best case scenarios, however, RF interference can significantly impact this range. The data transmit rate in an ideal scenario is 1 Mb/s. A significant downside to BT4 is that it has a small payload (message) size when compared to other methods and cannot send the full broadcast RID data. The payload size of only 31 bytes means that multiple messages must be sent to transmit all the required data and the authentication mechanisms in place are limited to verification of static information (ASTM International, 2020). Figure 8 (Cox, 2021) shows the broadcast message encoding for a BT4 RID message.

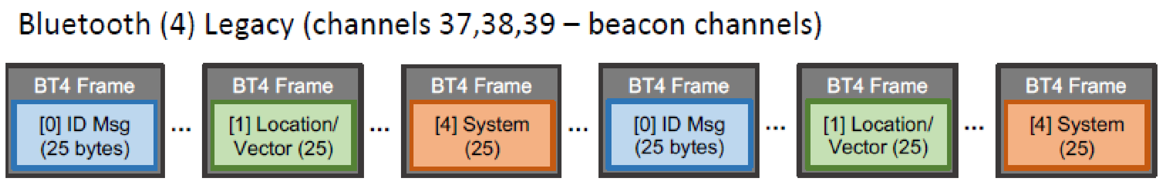


Figure 8. Bluetooth 4 message encoding.

## 6.2 Bluetooth 5.0

Bluetooth 5.0 (BT5), while similar in some ways to BT4, provides better performance and more options to users. It can operate with a transmission rate of 2 Mb/s or at a much lower rate of 500 kb/s for increased range and reliability (Spörk, Boano, & Römer, 2019). It also has a payload size of 255 bytes, allowing broadcast RID messages to be sent in a single transmission. This allows for a full authentication message to be attached so the entire message can be verified. Figure 9 (Cox, 2021) shows the message encoding for an RID message sent with BT5.

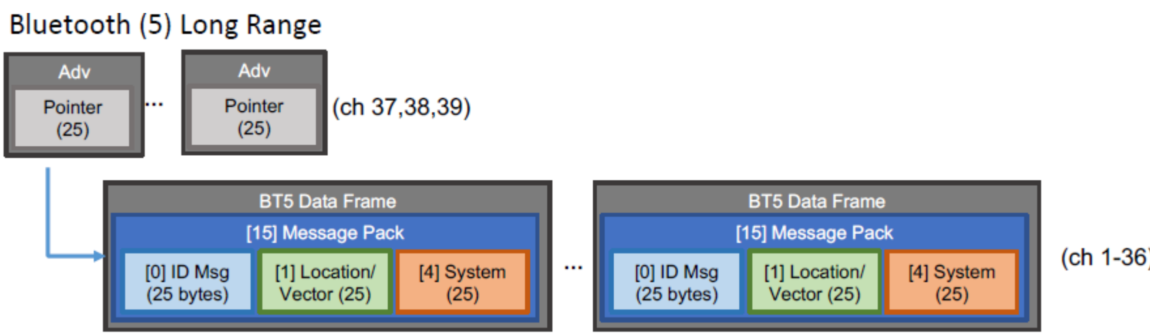


Figure 9. Bluetooth 5 RID message encoding.

The lower transmission rate allows BT5 to reach ranges upwards of 1 kilometer and nearly 4 times that of BT4 when operating in the same environment, especially when paired with a power amplifier (ASTM International, 2020). However, this range can still be limited due to RF interference. While BT5 transmitters are widely available, they are not commonly included on current UAS and would have to be affixed to an existing UAS or integrated into the design of future UAS. Unlike BT4, many devices, or receivers, have not fully adopted BT5 since its release in 2016. Android and Apple have only recently started implementing BT5 in their smartphones, but it is still not as prevalent as BT4. The ASTM standard states that those who may be transmitting BT5 must also transmit in the BT4 legacy mode to ensure that the message will be compatible with devices that do not have BT5 capabilities. A dongle, ground station, or laptop with USB receiver can also be used to achieve the BT5 broadcasts.

## 6.3 Wi-Fi Neighbor Awareness Network

Wi-Fi NAN, also known as Wi-Fi Aware, extends the capabilities of traditional Wi-Fi without the need for traditional network infrastructure, internet connection, or GPS signal. According to the Wi-Fi Alliance, it is "positioned to provide peer-to-peer connectivity in highly mobile environments" (Wi-Fi Alliance, n.d.), making it very suitable to the needs of RID systems. Wi-Fi operates at a higher transmit speed (6 Mbps) and thus must operate at a higher power level. It operates in the 2.4 GHz and 5 GHz bands with device discovery occurring in the 2.4 GHz band on channel 6. The ASTM standard states that rural environment tests conducted at 14 dBm showed a range of over 1 km, however, typical power levels will be higher than this and could result in ranges of more than 2 km in Europe (20 dBm) and more than 4 km in the US (26 dBm) (ASTM International, 2020). Similar to BT5, Wi-Fi NAN can send all necessary data in a single message but can also have its range limited by RF interference. Figure 10 (Cox, 2021) shows the encoding for an RID message.

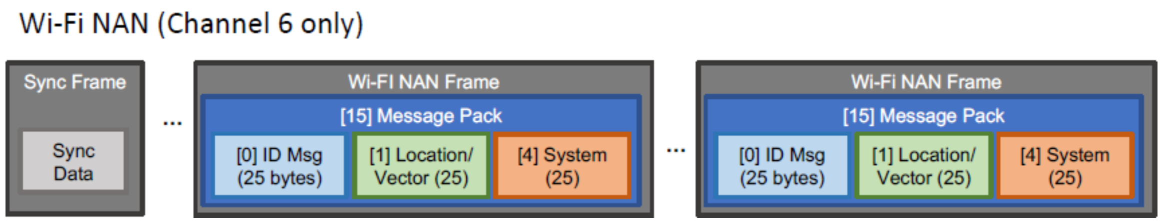


Figure 10. Wi-Fi NAN RID message encoding.

The ability to receive Wi-Fi NAN messages has become increasingly common on most mobile devices, specifically Android which started supporting it in 2017. Apple iOS devices do not currently support Wi-Fi NAN. A major advantage that Wi-Fi NAN has over BT4 and BT5 is that most if not all modern UAS have some form of Wi-Fi radio or transmitter onboard them already. This broadcast method could easily be supported without the addition of a module or engineering of future models through a firmware update if the UA does not already have it enabled (ASTM International, 2020). Wi-Fi NAN can also leverage WPA2 or WPA3 protocols giving it an added layer of security.

### 6.4 Wi-Fi Beacon

Wi-Fi Beacon, while not included in the ASTM standard, is presented as a broadcast method by the Aerospace and Defense Industries Association of Europe – Standardization (Aerospace and Defence Industries Association - Standardization , 2021) for the European Union (EU). It can be used in the United States as well to meet the FAA's rules as it provides the required message elements. Like Wi-Fi NAN, there is no need for the client device to be connected to any sort of infrastructure as the connection can be made without it. The client, or UAS in the case of RID, passively scans until it receives the beacon frame from an access point. The beacon frame is periodically transmitted from this access point, containing the RID information (Zehl, Zubow, & Wolisz, 2017). Wi-Fi Beacon is currently only supported by Android devices; however, the update rate is extremely low (virtually nonexistent) unless Wi-Fi "scan throttling" is turned off. This increases the update rate and allows for the RID messages to be received by the device at a rate that is sufficient. An RID message sent with Wi-Fi Beacon will have the following encoding in figure 11 (Cox, 2021).

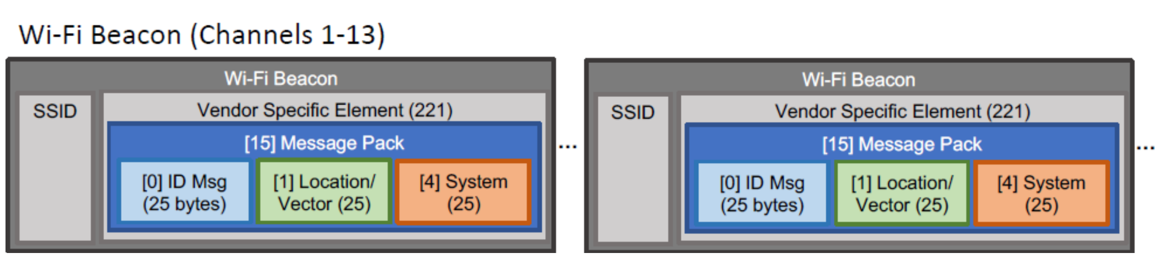


Figure 11. Wi-Fi Beacon encoding of an RID message.

# 7 REMOTE ID USE CASES

## 7.1 Current Uses of Remote ID

The ASTM RID standard states that there are two broad categories of use for RID in UAS. The first, and most important, being security and public safety needs. This allows for law enforcement and federal security agencies to track UAS and quickly and easily identify them. The second use case is providing the general public with RID information access and allowing them to use it for a variety of reasons. The ASTM Standard Specification for Remote ID and Tracking (ASTM International, 2020) covers a variety of example use cases for both of these broader categories. Simple uses of RID can be things like officials responding to a report of a suspicious UAS or providing security during a public event. RID also enables a higher degree of security around critical infrastructure and areas where heightened awareness is needed. For example, continuous use of RID around an airport or power station would provide an additional layer of security from nefarious UAS. In this case, public safety officials or a private company could make use of RID to increase their awareness of the low-altitude airspace around the infrastructure. The ability to provide proactive security or give public entities and citizens the ability to report a suspicious UAS is the main focus of RID as it aims to maintain the safety of the NAS. Use cases that are becoming increasingly important are UAS operating under Unmanned Aircraft System Traffic Management which in turn will also help support beyond visual line of sight (BVLOS) operations. RID is intended to act in an important role as the backbone of these concepts for UAS as they become increasingly prevalent over the coming years. RID aims to create an environment for low-altitude drone operations that is similar to that of the FAA air traffic services for aircraft.

## 7.2 Future Uses of Remote ID

As RID becomes more prevalent, it will become more intertwined with future technologies. RID is a flexible technology that, although intended as a security and safety measure, can act as an enabling technology for many potential future scenarios. The FAA has established a Drone Advisory Committee (DAC) that has investigated some of these future uses of RID. One such case is how RID can increase situational awareness for pilots in low altitude airspace where there may be a high number of UAS. After exploring the issue, the DAC found that many pilots expressed interest in having access to the RID information, but many thought it would increase their workload (Federal Aviation Administration, 2021). Ultimately, many think that the trade-off for having this slightly increased workload is outweighed by the increase in safety for both manned pilots and UAS pilots. Inclusion of RID into piloted aircraft is a concept that could be beneficial to those that participate in the NAS, but there needs to be human factors considerations made to study how it will ultimately affect pilots.

The largest and perhaps most significant milestone for UAS integration into the NAS is the establishment of a UAS Traffic Management System (UTM). Development of a UTM will be a large undertaking that is dependent on a variety of factors with RID at the forefront as stated by the DAC.

> *"The FAA and the Industry has described RID as a major first step toward the development of a total UTM solution for operations in the low-altitude airspace." (FAA Drone Advisory Committee, 2021)*

While network RID solutions are the main driving force behind UTM systems, the DAC has stated that to make it truly successful there must be a way to implement Broadcast RID as it will be the more prevalent method for the multitude of reasons previously discussed in this document. RID information can be captured by sensors and fed to services like the System Wide Information Management (SWIM) program or future UTM services that will disseminate the RID data to users of the UTM and NAS. The location and security information that RID has been developed to provide will likely put it at the forefront of future conversations and implementation of UTM services. It is also likely that RID will also be supported by the inclusion of UTM technologies allowing it to become easier to use and more prevalent, creating a synergy that creates a safer environment for drone users (Federal Aviation Administration, 2020).

The potential of RID could also be leveraged to help facilitate BVLOS operations by enabling accountability and traceability for users flying BVLOS. This is an inherent capability of RID, but it becomes incredibly important in a scenario where the pilot of a UAS will not be collocated with their UAS and can be virtually anywhere within the communication range of it (Federal Aviation Administration, 2020). Beyond this security measure, RID could also be used in a detect-and-avoid (DAA) system to provide additional situational awareness to the UAS and/or operator in support of BVLOS operations.

# 8 LIMITATIONS

## 8.1 GPS Accuracy

There are many factors that affect GPS accuracy. These include satellite signal blockage, receiver design features, and atmospheric conditions. Satellite signal blockage tends to be the greatest hindrance to GPS accuracy. Buildings, bridges, and trees can all affect the position accuracy of a GPS. One study in 2014 found that GPS enabled smartphones are typically accurate within 4.9 meters on average (Diggelen, 2015). The study also found that this accuracy worsens near buildings, bridges, trees, and any object that can block a direct path from the satellite to the receiver as seen in Figure 12 (TechDesign, 2021). Signal reflection can also degrade GPS accuracy. Multiple reflections of the GPS signal from buildings, walls, trees, and highways can create positioning errors or delays.

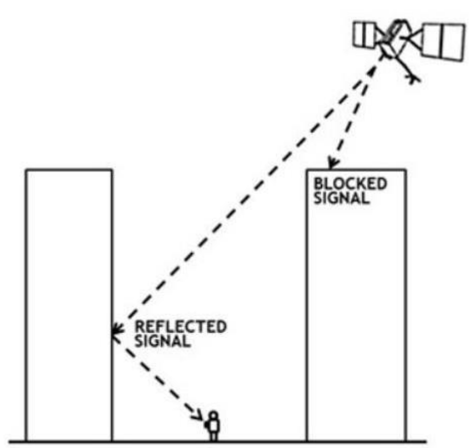


Figure 12. GPS signal blockage and reflection from obstacles.

Receiver design features and quality also greatly affect the accuracy of a GPS. For instance, most civilian GPS receivers use a single frequency while military GPS receivers use two frequencies, resulting in higher location accuracy for military GPS receivers. How many Global Navigation Satellite Systems (GNSS) and in which frequency bands a GPS receiver can support also directly affect the performance of the receiver. The more GNSS systems and frequency bands a GPS receiver can support, the better the receiver can perform. The hardware such as the antennas used in the receiver also greatly affect the performance of the receiver and how accurately it can provide positioning data. The weather environment, such as rain and high humidity, can also affect the accuracy of a GPS system; however, the weather's effect on GPS location accuracy is so low that it is considered negligible (National Coordination Office for Space-Based Positioning, Navigation, and Timing, 2021).

### 8.2 RF Interference

Bluetooth and Wi-Fi share the same 2.4GHz frequency spectrum which can cause radio signals to interfere with each other. In the RF spectrum, the Bluetooth channels are much smaller than that of the Wi-Fi channels. If there is excessive use of Wi-Fi in the same area of the spectrum, many of the Bluetooth channels in that area could already be in use. Bluetooth devices near Wi-Fi transmitting devices (and vice versa) can also cause interference and performance issues. Many Wi-Fi routers transmit on multiple channels simultaneously and if there are excessive Wi-Fi signals in proximity taking up a majority of the spectrum, this can prevent a Bluetooth device from having an open spectrum to be able to support frequency hopping, where the device changes what frequency it is broadcasting on. Essentially, the spectrum can get flooded to a point where frequency hopping will not be a sustainable method to solve the RF interference issue (Marcel, 2020). Since they are being sent over Bluetooth and Wi-Fi, RID signals can succumb to RF interference. The distance at which a signal could be received can decrease, or in areas where there is a lot of RF traffic the signal could struggle to be received due to the interference.

## 9 CONCLUSION

The implementation of RID is aimed at increasing the overall safety and security of to the NAS. It has been incrementally built up to by the FAA through regulations that have continued to focus the safe operation of UAS . The FAA's recent RID ruling, 14 C.F.R. § 89, allowed public comments on the RID rule prior to its adoption from those who are affected by it – allowing for a more comprehensive final rule to be developed. Broadcast RID will be the main method of adherence at the time of writing this report and is made possible by wireless technologies such as Bluetooth and Wi-Fi. Their widespread usage/support and promising performance characteristics have made them the primary choices for RID. The required message elements ultimately provide information that can be used in a variety of ways and will continue to build upon UAS capabilities while enabling future technologies. Validation of the ASTM International RID standard is still underway; however, initial testing and demonstrations have shown promising results from prototype standard UAS and module-based RID systems.

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