NASA

UAS Air Traffic Management (UTM)

Small Unmanned Aircraft Electromagnetic Interference (EMI) Initial Assessment

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Small UAS EMI Initial Assessment

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Small UAS EMI Initial Assessment

INTRODUCTION

The Technical Challenge:

How to manage millions of small UAS (sUAS) that will operate in low altitude airspace, outside of conventional air traffic control

Lack of EMI characteristics, lack of RF measurement practice on sUAS

NASA's UAS Traffic Management Project:

Develop comprehensive, validated airspace operations and integration requirements to safely enable large-scale persistent access to sUAS

UTM Command and Control (C2) Communications

Analysis of UTM C2 approaches, including measurements of the RF environment at altitude using an RF channel sensing payload carried by a DJI S1000 sUAS

Need to characterize the EMI performance of the S1000 sUAS in order to enable correct interpretation of RF channel sensing data

UTM Project Overview

What is Unmanned Aircraft System Traffic Management (UTM)?

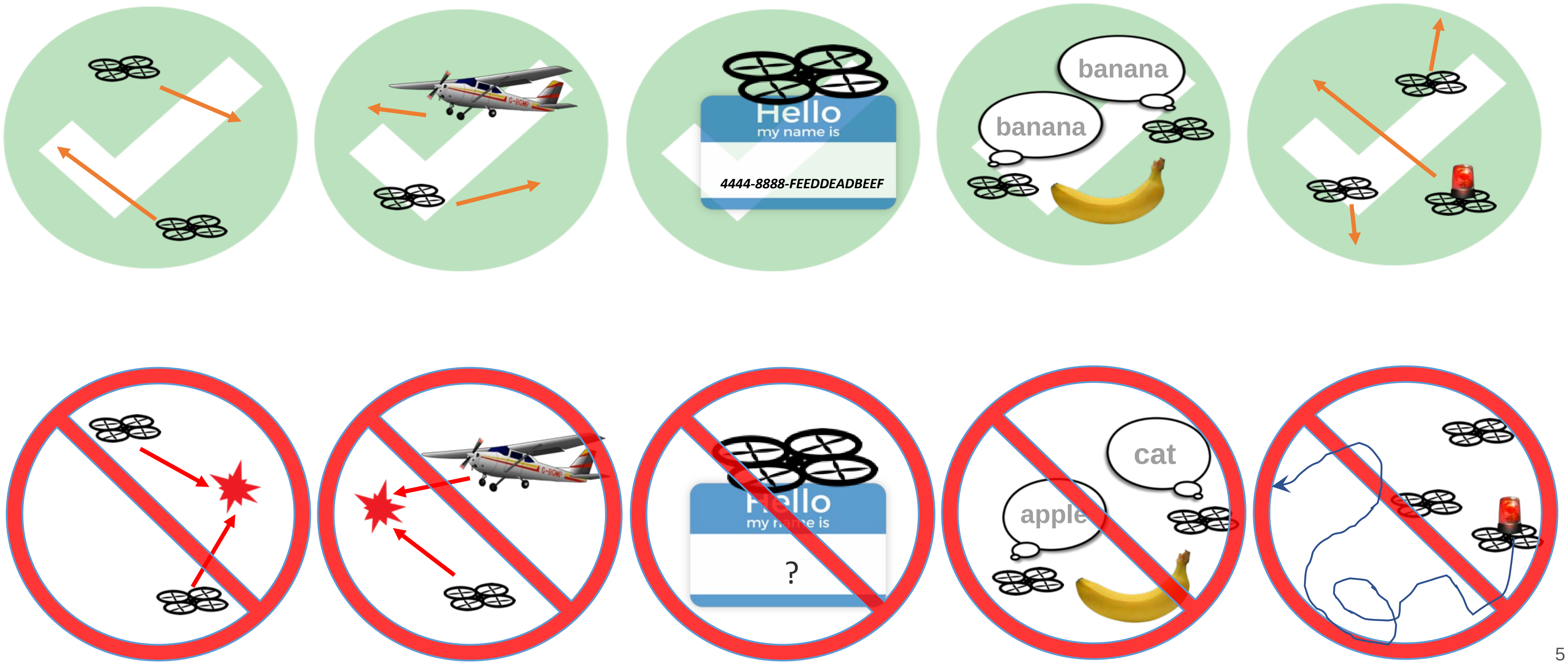
- **UTM is an "air traffic management" ecosystem for uncontrolled operations**
- UTM utilizes industry's ability to supply services under FAA's regulatory authority where these services do not exist
- UTM development will ultimately identify services, roles/responsibilities, information architecture, data exchange protocols, software functions, infrastructure, and performance requirements to enable the management of low-altitude uncontrolled UAS operations

UTM addresses critical gaps associated with lack of support for small UAS

UTM Project Overview

UTM Principles

(a.k.a. Things That UTM Will Help With…)



UTM Project Overview

Risk-based Conflict Mitigation Strategy

TCL1 (Remote)	TCL 2 (Rural)	TCL 3 (Suburban)	TCL 4 (Urban)
Visual Line of Sight	**Beyond Visual Line of Sight**	**Beyond Visual Line of Sight**	**Beyond Visual Line of Sight**
Notice of Operation	**Intent Sharing**	**Intent Sharing**	**Intent Sharing**
Position-Sharing (Optional)	**Strategic De-confliction**	**Strategic De-confliction**	**Strategic De-confliction**
	Geographic Containment	**Geographic Containment**	**Geographic Containment**
		Conflict Alert	**Detect and Avoid (DAA)**
		Detect and Avoid (DAA)	**Vehicle-to-Vehicle (V2V)**

RF Channel Sensing Payload

Overview and Description

Potential UTM C2 Communications

A number of candidate technologies are being tested for application to UTM C2 communications

Of particular interest are commercial cellular networks – LTE/4G, as well as the industrial, scientific and medical (ISM) bands

The RF channel sensing payload will examine the RF environment in the relevant LTE/4G and ISM bands

LTE Bands of Interest

Band	Base Station Transmit Bands	User Equipment Transmit Bands
700 MHz	717-768 MHz	699-716 MHz, 777-798 MHz
800 MHz	832-869 MHz	807-824 MHz
850 MHz	852-894 MHz	814-849 MHz
1700 MHz	N/A	1710-1780 MHz
1900 MHz	1930-1995 MHz	1850-1915 MHz
2100 MHz	2110-2170 MHz	1920-1980 MHz
2300 MHz	2350-2360 MHz	2305-2315 MHz
2500 MHz	2496-2690 MHz	2496-2690 MHz

ISM band of interest

5.725-5.875 GHz

RF Channel Sensing Payload

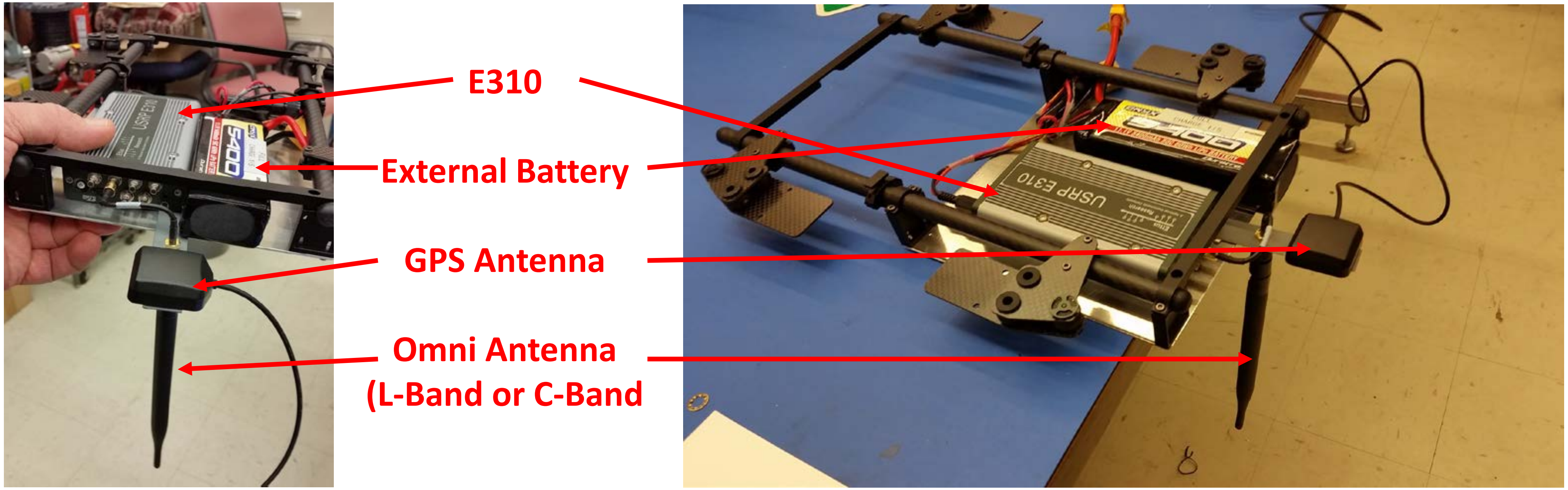
Overview and Description

RF Channel Sensing Payload

Design based on software defined radio (SDR), Ettus Models E310, E312

0-6 GHz receive band; A-to-D conversion and post-processing delivers a frequency-domain spectrum analysis of a measured frequency band.

Payload mounts to the bottom of the S1000 (shown later)



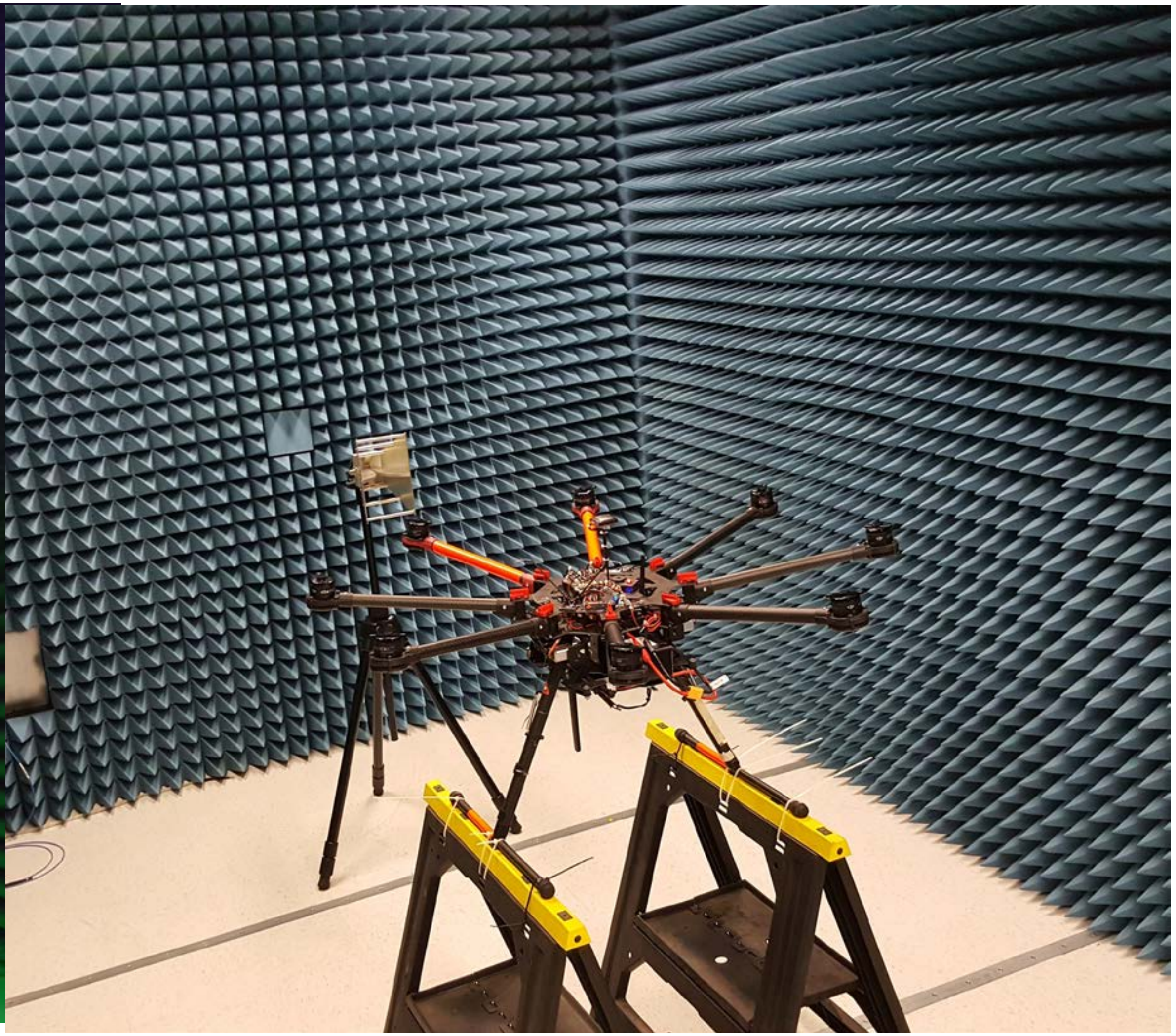
DJI S1000 Description

Photo Credit: DJI

Manufacturer/ Model:	Dà-Jiāng Innovations Science and Technology Co., Ltd (DJI)/S-1000+
Configuration:	Octocopter
General Characteristics:	
Length	100 cm
Height	48 cm
Weight	4.2 kg
Payload Weight	5 kg
Propulsion:	
Motor Power	500 W
Motor RPM	9600 RPM
Flight Parameters:	
Max Ground Speed	13.4 m/s (30 MPH)
Battery	6S 16000 mAh LiPo
Flight Time	15 Minutes

For Electromagnetic Interference, considered as a representative model for octocopter with carbon fiber frame

DJI S1000 Description



EMI Assessment Overview

Identify and quantify any EMI signals in the measurement bands of interest

EMI signals originating in the sUAS vehicle carrying the payload in the bands of interest can confuse the identification of the signals we are trying to measure

The EMI assessment is intended to identify any such signals, enabling any in-band EMI signals to be known and subtracted from data captured during resulting RF channel sensing flight tests

It may also be possible to reduce or eliminate EMI sources prior to flight testing if they prove to be particularly problematic

The S1000 sUAS consists of several electrical and mechanical components potentially capable of creating EMI

Careful measurement of the EMI environment created by the S1000 while in an operating configuration was conducted in the RF Test Lab (RTL) at the NASA Ames Research Center

NASA Ames RTL Description

Facility for accurate and precise EMC testing in a shielded environment

RTL conducts high precisions RF measurements and full compliance EMC (electromagnetic compatibility) testing

Such testing can be expensive, but eliminating or delaying EMC/EMI testing can be very risky; a problem identified late in the project life cycle can be extremely expensive to remediate or may even endanger the mission

The RTL provides a safe, secure, accurate/precise and affordable solution

Tests are conducted in the RTL EMI/RFI Shielded Enclosure

EMI Test Method

General Approach

Compliance level standards per MIL-STD-461 - equipment and personnel

Electrical integration and RF test equipment enables flexible testing environment

As an example of similar types of testing occurred on Astrobee, a free-flying robotic payload bound for the International Space Station. The lab was able to help Astrobee pin point precise EMI sources during their hardware development build

The RTL’s RFI/EMI shielded enclosure provides attenuation levels of 56 dB at 1 kHz and 100 dB from 200 kHz to 10 GHz

The enclosure is equipped with RF absorber that completely covers all walls and ceiling adding an additional -15dB to -50dB of attenuation from 450 MHz to 40 GHz.

EMI Test Method

S1000 Testing

Measurements were conducted using a receive antenna consisting of a double ridge guide horn specifically designed to meet MIL-STD specifications for frequencies from 700 MHz to 10 GHz.

Calibration of the test configuration and emissions measurements were conducted with an Anritsu MS2035B Vector Network Analyzer + Spectrum Analyzer

Measurements were taken in smaller frequency bands covering the areas of interest for the RF channel sensing payload, rather than across 0 to 6 GHz, allowing lower resolution bandwidths without excessive measurement times:

700 MHz-930 MHz

1700 MHz-1800 MHz

1900 MHz-2700 MHz

5700 MHz to 5950 MHz

EMI Test Method

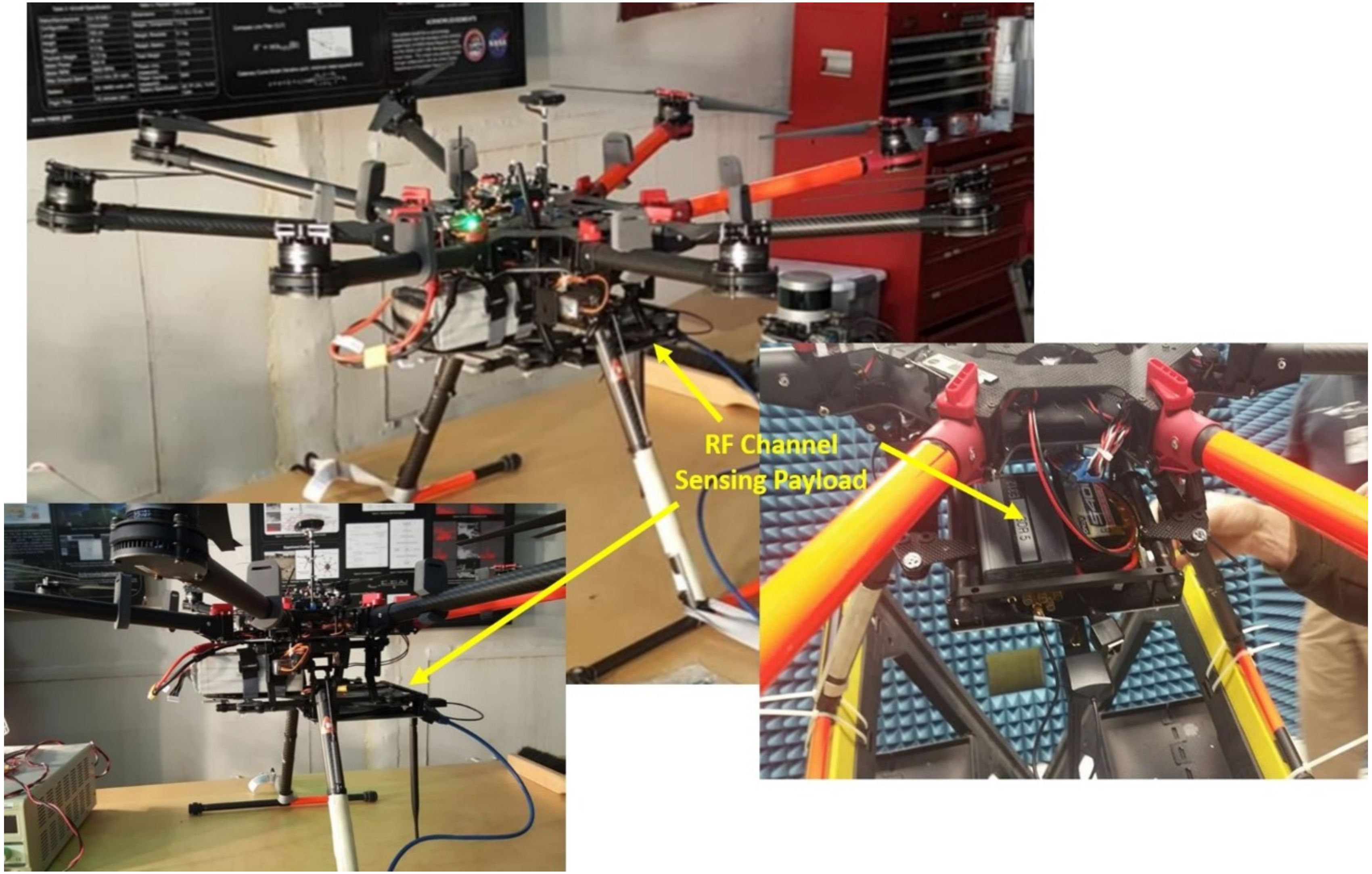
S1000 Testing

The test configuration inside the EMI/RFI shielded enclosure

EMI Test Method

S1000 Testing

Some views of the payload mounted to the S1000



EMI Test Method

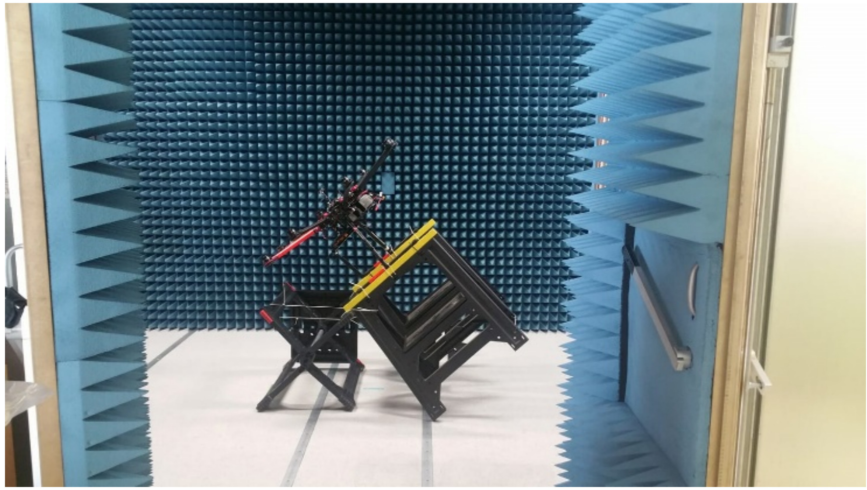
Test Configurations

S1000 was tested at three rotor RPM levels – ambient (0 RPM), slow (5500 RPM), and fast (8800 RPM) - For safety reasons, propellers were removed

Six orientations of the S1000 relative to the receive horn antenna were tested – with the S1000 front, left, right, top, bottom, and rear facing the receive horn antenna

EMI may originate from different S1000 components and be shielded or reflected by the S1000 structure or payload

S1000 in Front Configuration



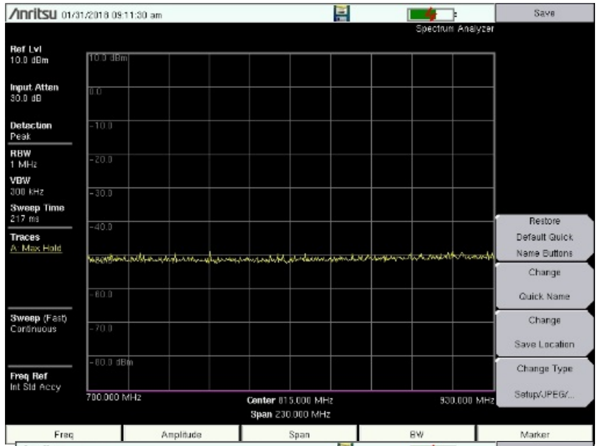
S1000 in Top Configuration

EMI Test Results

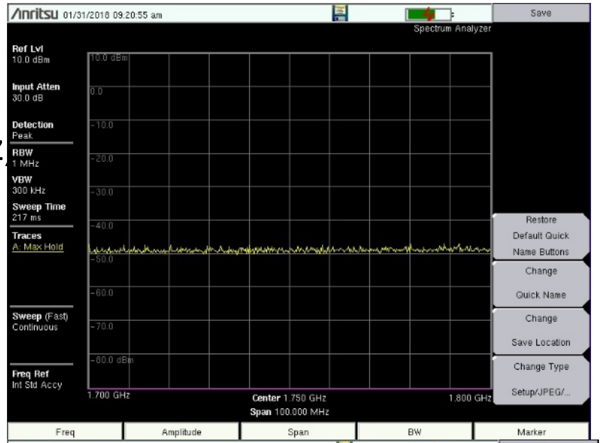
Ambient Measurements (0 RPM)

No EMI signals observed in the four test bands - indicates that there are no other EMI signals present in the measurement attributable to other sources

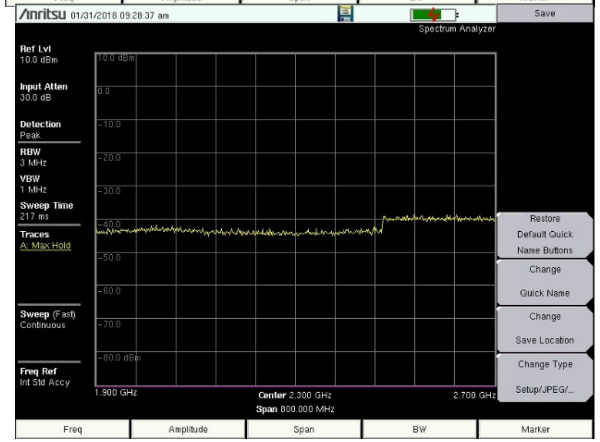
700 MHz-930 MHz,
Front Orientation,
Ambient Condition,
1 MHz RBW



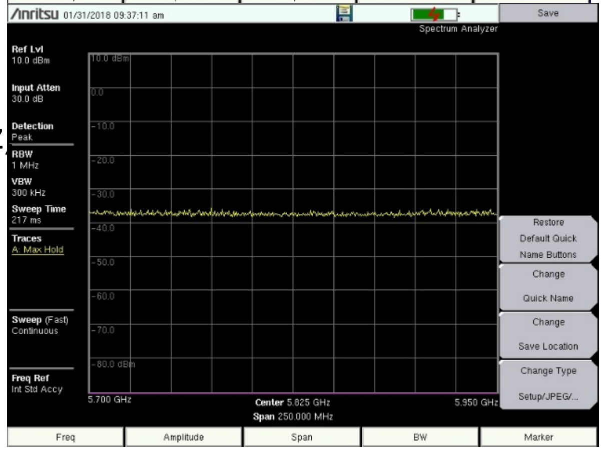
1700 MHz-1800 MHz,
Front Orientation,
Ambient Condition,
1 MHz RBW



1900 MHz-2700 MHz,
Front Orientation,
Ambient Condition,
3 MHz RBW



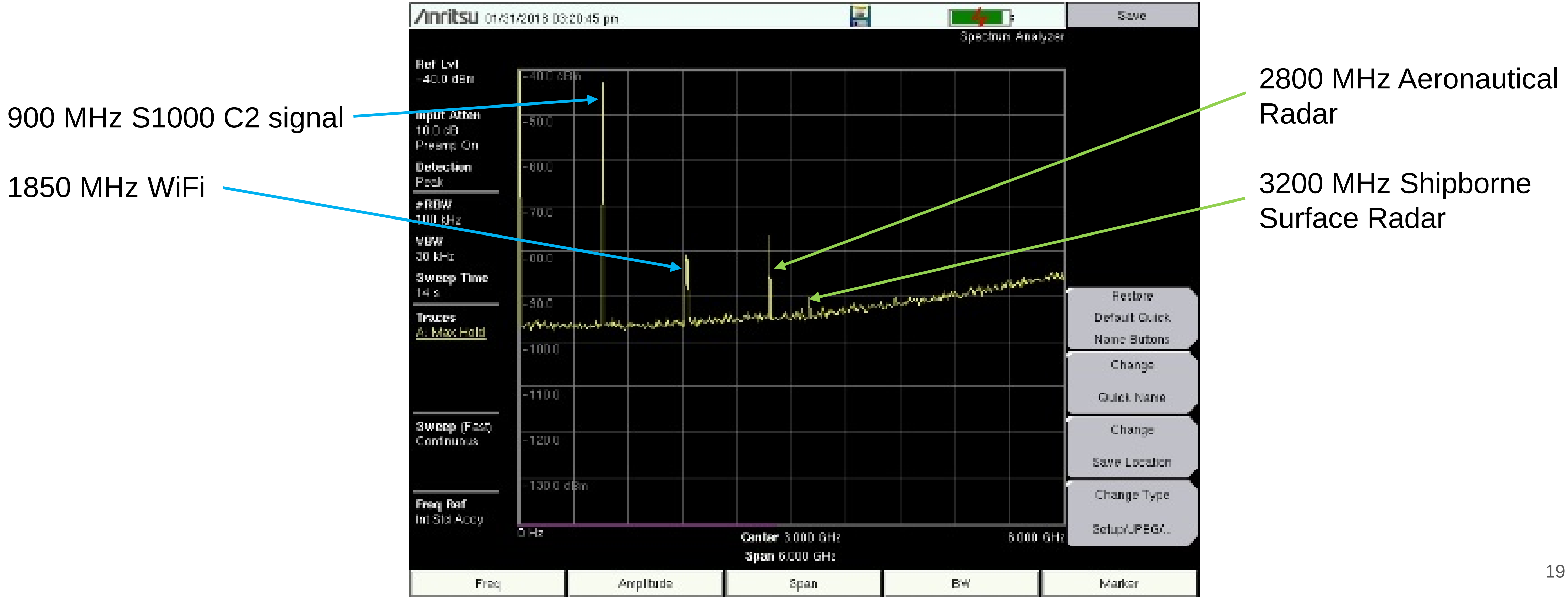
5700 MHz-5950 MHz,
Front Orientation,
Ambient Condition,
1 MHz RBW



EMI Test Results

Low RPM (5500 RPM)

No EMI signals observed in the test bands of interest. There were three other signals not in the bands of interest, as shown in this 0 to 6 GHz spectrum scan (100 kHz RBW).



EMI Test Results

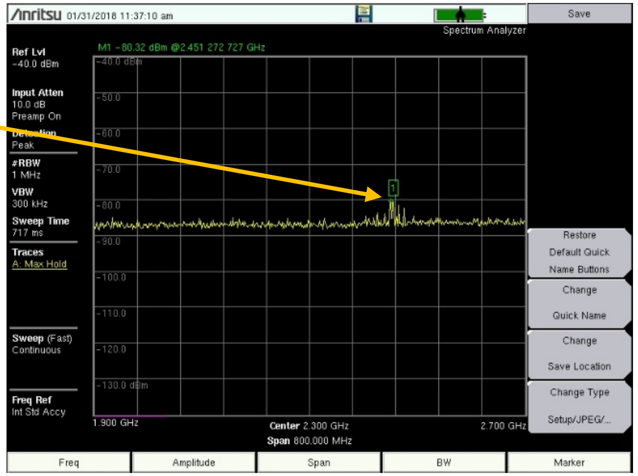
Low RPM (5500 RPM)

In all testing, no effects of S1000 orientation were observed except the following

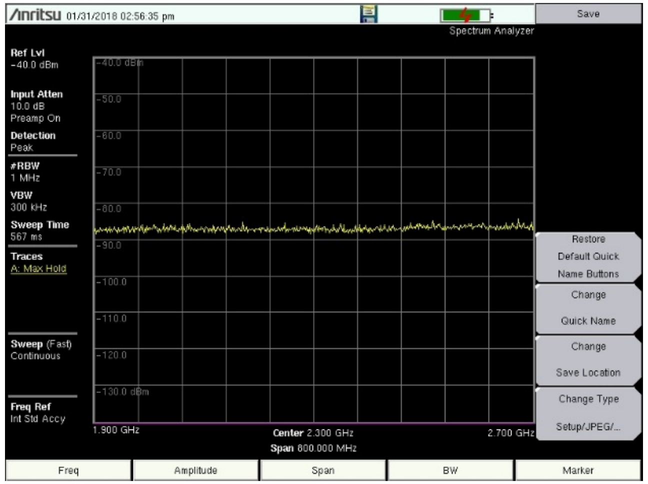
In the 1900-2700 MHz range we see signals at 2400 MHz, attributable to the indoor WiFi network inside the building - these signals are not seen in the top and bottom S1000 orientations

Since these signals do not originate from the S1000, it was concluded that the top and bottom orientation block this signal from reaching the receive antenna

2400 MHz WiFi



1900 MHz-2700 MHz, Rear Orientation, Low RPM, 1MHz RBW



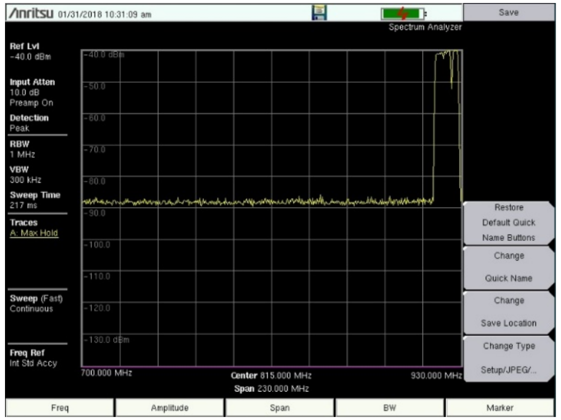
1900 MHz-2700 MHz, Top Orientation, Low RPM, 1MHz RBW

EMI Test Results

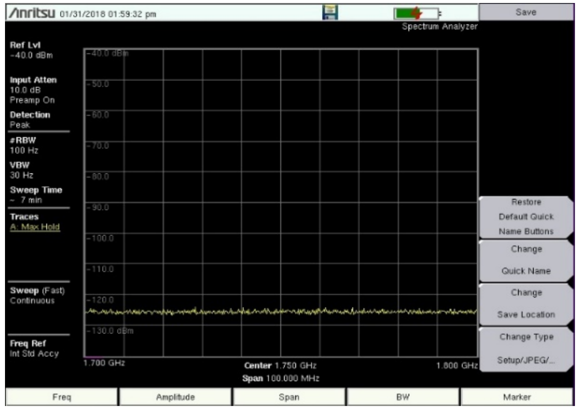
High RPM (8800 RPM)

No EMI signals observed in the test bands of interest.

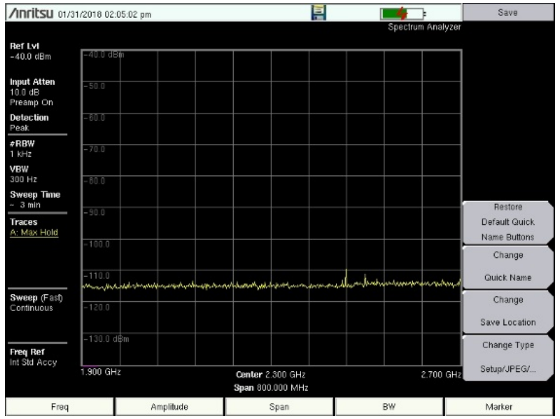
700 MHz-930 MHz,
Front Orientation,
High RPM Condition,
1 MHz RBW



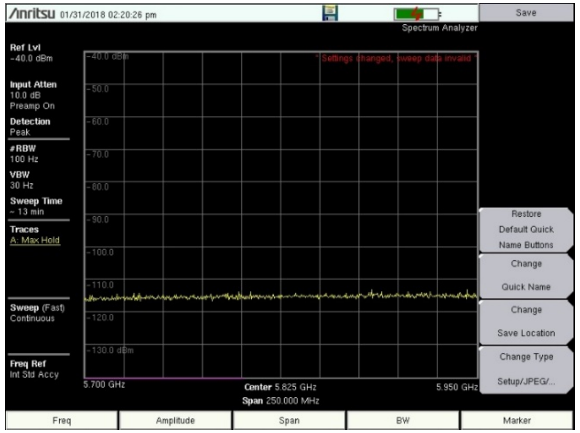
1700 MHz-1800 MHz,
Front Orientation,
High RPM Condition,
100 Hz RBW



1900 MHz-2700 MHz,
Front Orientation,
High RPM Condition,
100 Hz RBW



5700 MHz-5950 MHz,
Front Orientation,
High RPM Condition,
100 Hz RBW



Summary and Conclusions

The S1000 does not produce measurable EMI in the bands of interest

There are emissions from the S1000 C2 wireless link that do not appear in the RF channel sensing payload’s bands of interest

There are some other signals observed that are traceable to known external sources and not considered to be originating from the S1000 - none of these appear in the bands of interest

The RF channel sensing payload should be able to make measurements free from interpretation errors due to S1000 EMI

Similar sUAS should produce similar EMI characteristics

Given these results and the main components of the S1000, a carbon fiber frame with eight motors, one can expect similar EMI from similar sUAS types

However, sUAS platforms significantly different (e.g. aluminum, plastic, foam construction) may need EMI testing

EMI testing methods and procedures applicable to other types of sUAS have been presented in this paper

Thank you!

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Backup Charts

UTM Project Overview