Wireless Broadband Solutions for Unmanned Ground Vehicles

State-of-the-art wireless MIMO for

Command and Control + long range video streaming

Wireless Communication Link:
The Lifeline of Unmanned Ground Vehicles

Fueled by growing demand, unmanned ground vehicle (UGV) manufacturers are rapidly improving the performance of their systems in terms of range and capabilities. However, an acute pain point for UGV designers is finding communication solutions that allow their systems to reach their full potential, including maintaining full functionality from several hudred meters away. The communications link between a rover and the control station is the lifeline, and it is necessary to have a highly reliable, low latency, high throughput wireless link for Command, Control and streaming sensor data (e.g. 4K video).

Doodle Labs has an extensive portfolio of wireless building blocks, developed specifically with the state-of-the-art wireless technolgies. Our development is focused on leveraging the benefits of COFDM and MIMO technology to address the inherent RF challenges that unmanned vehicles face. As a part of this effort, Doodle Labs has developed a set of UGV-focused features within our BII® technology that provide low latency command and control channel, extend the rover's communication range and support Near Line of Signt (NrLOS) operations.

Doodle Labs' latest Smart Radio was designed with the requirements of Unmanned Vehicles in mind.

Smart Radio: High-Performance Wireless Broadband for UGV

The Smart Radio platform is a full-featured 2x2 MIMO radio and mesh router in a tiny form factor. It incorporates Doodle Labs' BII® technology, optimized for UGV applications that require mobile, and high-throughput wireless broadband links that can tolerate harsh RF conditions. Below are some of the salient features of the Smart Radio:

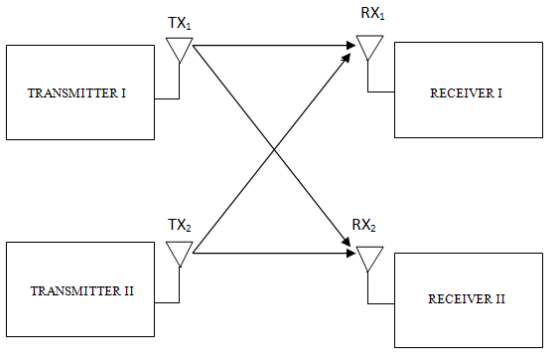
- Deep penetartion, Multi-path and NrLOS communication
- Adaptive Link Quality
- Communication Range
- Command & control and sensor data on a single link
- Encryption and immunity against cyber attacks
- Unlicensed, licensed and special-band operation
- Mesh networking
- Industrial-Grade Construction
- Minimal size, weight, and power consumption (SWaP)
- Ease of integration

Deep Penetration, Multi-path and NrLOS Communication

Most UGV missions don't occur in clean, interference-free, Line of Sight environments. Real world applications tend to be noisy with many competing devices operating on the same frequency bands. For many UGV applications, radio links that can penetrate deep and operate in NrLOS conditions is the most important criteria.

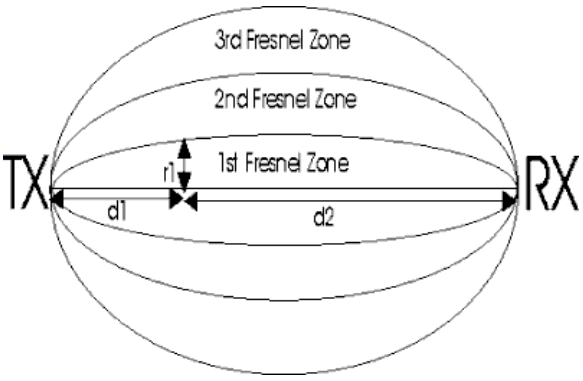
A detailed look at the UGV's operating environments show that there are numerous factors affecting the wireless performance. The UGVs are mobile deep inside manufacturing floors, warehouses,

tunnels and buildings. This creates significant RF challenges due to constantly changing link conditions. The effects of varying orientation, tilt and roll, multi-path reflections, antenna shadowing can drastically change the link quality between the rover and the control station.

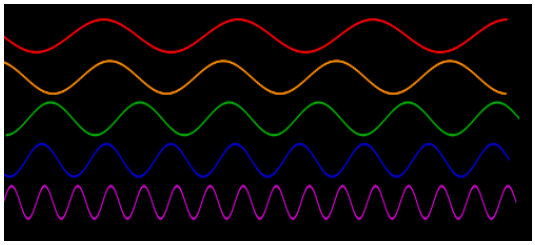


The MIMO technology used in the Smart Radio mitigates these risks through a host of advanced features like per packet rate adaptation from DSSS up to 64QAM, RF power control, Convolutional Coding, Forward Error Correction, ACK-retransmits, Maximal Ratio Combining, Spatial Multiplexing, and Space Time Block Coding. The 2x2 MIMO technology used in the Smart Radio provides antenna diversity and addresses the dynamic link conditions caused by the roll and pitch of the rover. The Smart Radio is finely tuned with precise, customized filters on its front-end. It has a receive sensitivity of up to -100 dBm, which is superior to any comparable product on the market. The high receive sensitivity allows the radio to handle the interference, and operate at long operating range.

Communication Range and the Laws of Physics



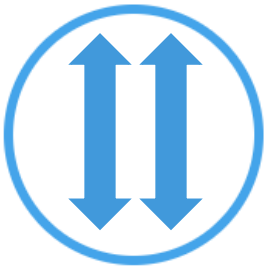
Because UGVs and their hand held control stations operate close to the ground, Fresnel zone obstruction plays a significant role in determining the range. Fresnel zone are ellipsoidal shaped regions in space (e.g. 1st, 2nd, 3rd), centered around the straight line of sight. Any obstructions in these regions causes the phase-shift, diffraction and polarization of the RF waves, affecting the link performance. As a rule, 60% of the 1st Fresenel zone should be obstruction free. There are many Fresnel zone calculators available online.



There are several ways to address the issue. Increasing the height of the control station will help to reduce the Fresnel zone encroachment. Using cross-polarized antennas will provide diversity. And using antennas with their E-beam tilting up will be helpful. Choice of operating frequency also requires consideration. For deep penetration, low frequencies are reccomeded. However, the Fresnel zone is larger for low frequencies and will create bigger Fresnel zone obstruction. On the other hand, higher frequencies have smaller Fresnel zone, but they can not penetrate deep inside the buildings. So a careful balance of the required range and operating frequency must be made. Doodle labs product portfolio covers frequency range from 100 MHz to 6 GHz, making it easier to design a data link for UGV.

Command & Control and Sensor Data on a Single Link

A single radio on a rover that can handle all communication needs mitigates the complexity of multiple data links and additional SWaP. The Smart Radio achieves this by applying different priorities to each packet of data.



The uplink command & control transmission to the flyer needs to be highly reliable with low latency. The Smart Radio has a special Ultra Reliable Low Latency Channel (URLLC) for transmitting C&C packets at the highest priority and enabling RF parameters that ensure reliable communication even in very noisy environments.

The downlink from the UGV to the control station often carries large amounts of sensor data, for which the Smart Radio has a concurrent optimized channel. Streaming 4K video requires about 20 Mbps throughput, while about 5 Mbps is required for HD video. The Smart Radio uses its optimized streaming sensor channel to transmit at these rates over long distances.

Encryption and Immunity against Cyber Attacks

Public Safety, Defense, and many Commercial applications transmit highly sensitive data. Over the air communications must be secure and the vehicles must be protected from unintended parties trying to gain access.

Applications that require maximum levels of protection can leverage the Smart Radio's 256-bit and 128-bit AES encryption capabilities. Built-in firewall and VPN capabilities defend against denial of service attacks. Additionally, the Smart Radio provides configurable noise filtration to defend against radio jamming attacks.

Unlicensed, Licensed, and Special Band Operation

International, Public Safety, and Defense customers have access to special frequency bands. The challenge for UGV developers is to build a system that doesn't need to be redesigned each time a customer requires a new operating frequency for their market.

The full portfolio of Smart Radios covers frequencies between 100 MHz and 4 GHz, with each model optimized to operate within a specific band. Each Smart Radio is form-factor compatible, allowing OEMs to switch the frequency band by simply inserting a different model. The Smart Radio's channel sizes are software-defined and can be as small as 3 MHz, opening up many opportunities for customers who have access to private spectrum

Mesh Networking

As use cases for unmanned systems get more complex, users often utilize multiple rovers and scattered access points. In addition, real world deployments mean that direct line of sight may be impaired. To overcome this challenge, Doodle Labs has integrated self-healing and self-forming mobile mesh technology to extend the operating range and support Non-Line of Sight situations.

Industrial-Grade Construction

The Smart Radio has been constructed using ruggedized, vibration-resistant components and casing. It operates within the industrial temperature range of -40°C to +85°C. Each individual unit is factory tested to ensure that performance and high quality standards are met.

Ease of Integration

Unmanned systems often have unique and complex architectures that vary with the vehicle controllers and CPUs that are incorporated. With an objective of creating a plug and play solution, the Smart Radio has Ethernet and UART interfaces to integrate with various design architectures. In addition, BII software provides additional remote management APIs to gain direct access to Smart Radio, allowing deep integration with the system's OS. See the appendix for system architecture diagrams.

Minimal Size, Weight, and Power Consumption (SWaP)

In most circumstances, SWaP is not an important consideration for the rover. However, minimal SWaP is an important requirement for the handheld controllers. Operating time is directly correlated to the power consumed by the system. While size and weight determine the usability of the controller. A central design objective for the Smart Radio was minimizing the overall footprint and weight of the radio. The 2x2 MIMO radio is only 65x57x11 mm in size and weighs just 60 grams.

Additional Doodle Labs Products for Unmanned Aerial Systems

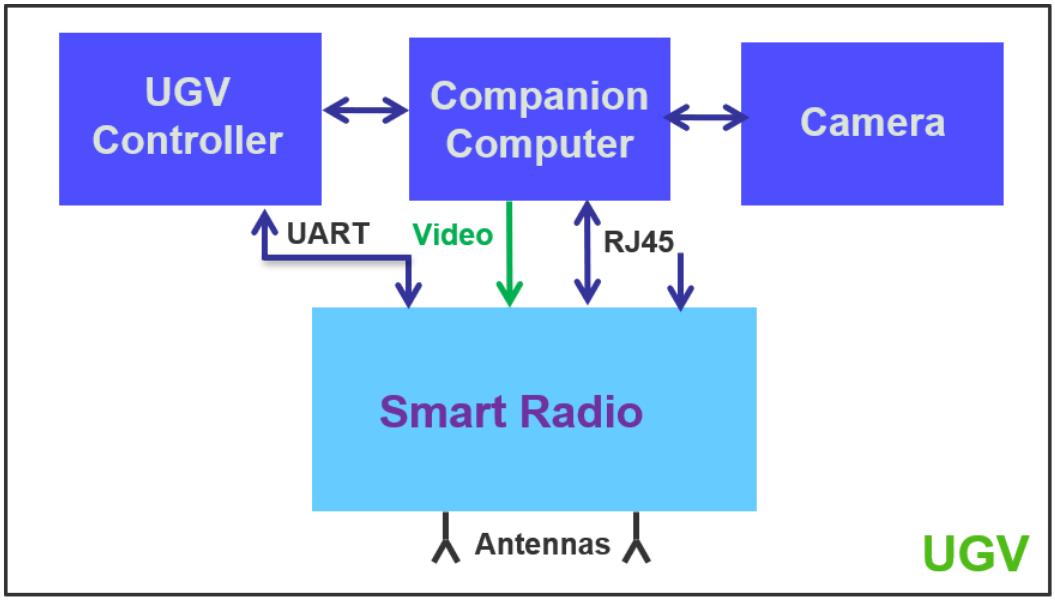
In order to serve the wide range of system architectures, Doodle Labs has four solutions that meet the unique needs of unmanned systems.

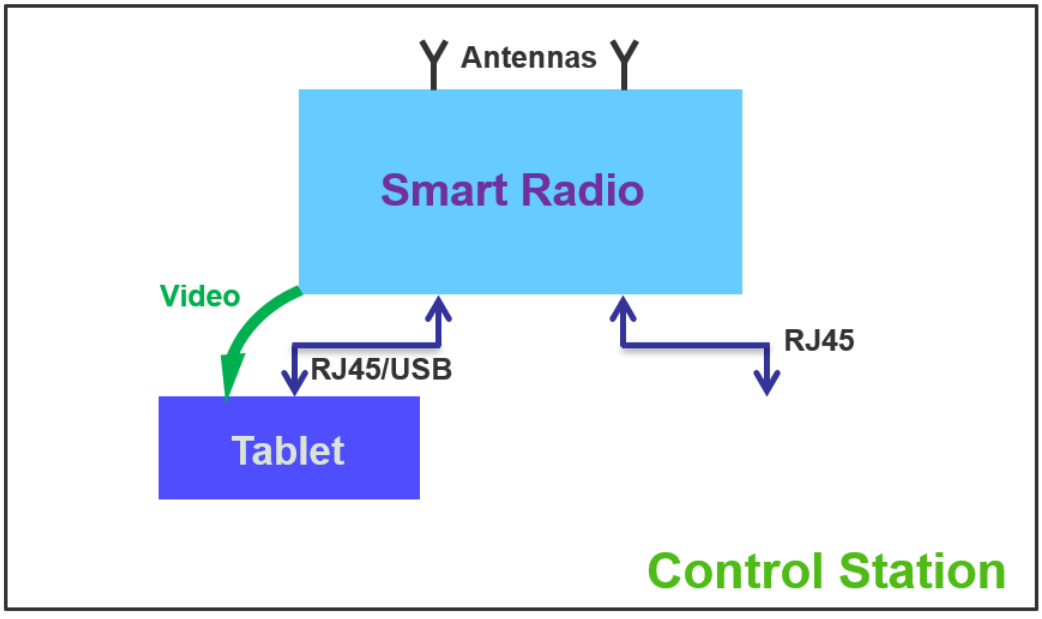
All the models in these product families are built upon a foundation of COFDM and MIMO technology to provide wireless broadband links in the most challenging RF environments.

Each solution can be considered a building block, and multiple blocks can be used in conjunction to construct a solution that meets the system's requirements. The block diagrams in the appendices illustrate how these products can be integrated in various UGV design architectures.

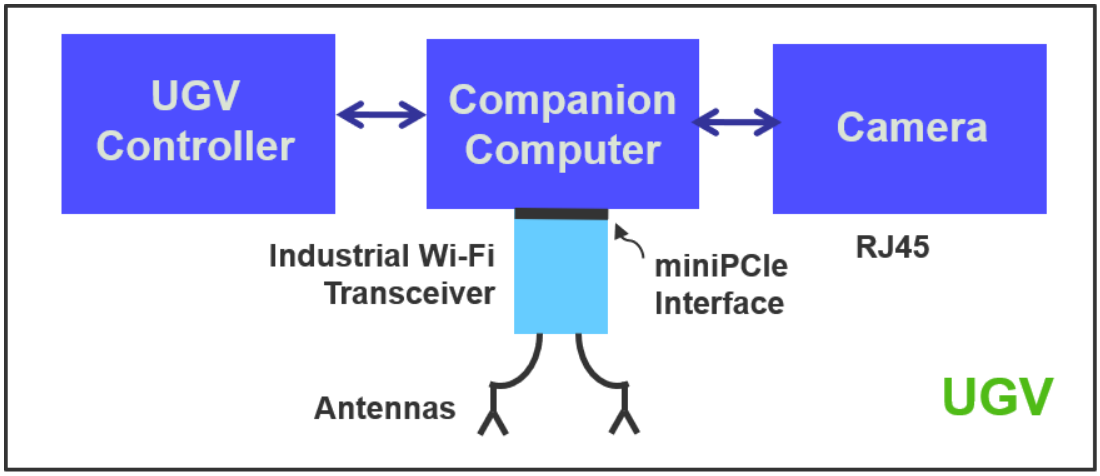
Product Family	Description	Frequency Range	RF Power	System Integration	Size Weight
Smart Radios	Full-featured 2x2 MIMO radio and mesh router in a tiny form factor; 2x Ethernet, UART	100 MHz ~ 4 GHz	33 dBm	Standalone router	65 x 57 x 11 mm, 60 grams
Industrial WiFi Transceivers	High-power, rugged WiFi (11ac and 11n) transceivers; miniPCIe	2.4 GHz, 5 GHz	30 dBm	CPU board, Linux/OpenWRT with ath10k/ath9k driver	30 x 50 x 4.8 mm, 12 grams
Special Band Transceivers	Frequency band-shifted WiFi transceivers; miniPCIe	100 MHz ~ 6 GHz	33 dBm	CPU board, Linux/OpenWRT with ath9k driver	30 x 50 x 4.8 mm, 60 x 56 x 6 mm, 52 grams
Front End Subsystems	Analogue SDR modules for frequency band shifting of WiFi and LTE signals, USB	100 MHz ~ 6 GHz	33 dBm	In-line module between radio and antenna	60 x 56 x 6 mm, 40 grams

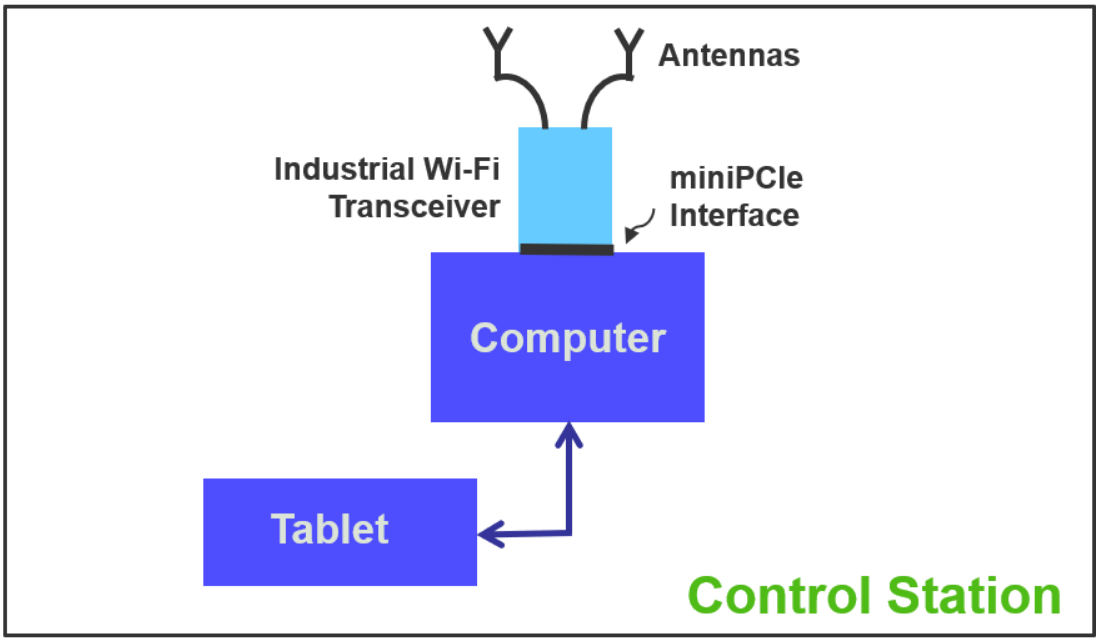
Appendix A – UGV with Smart Radio



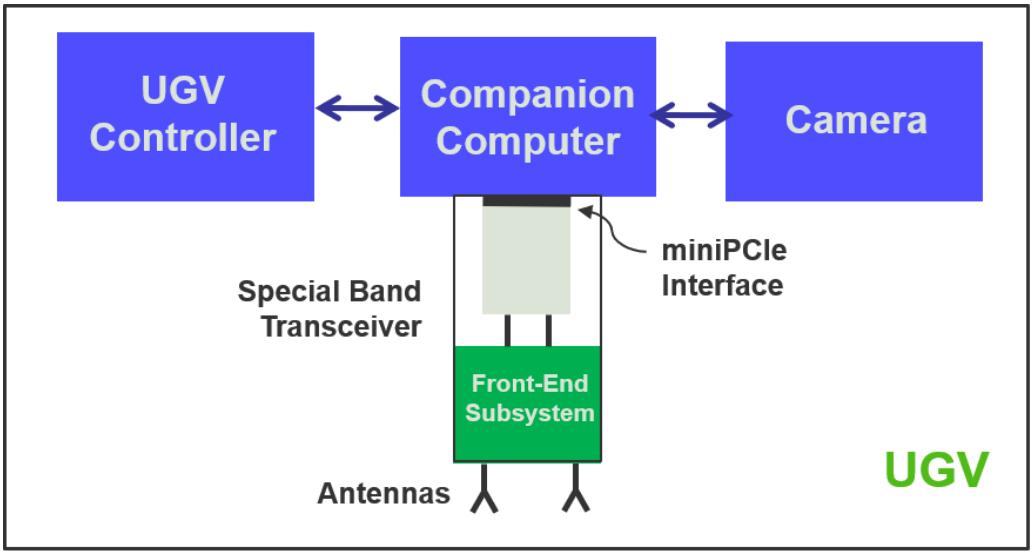


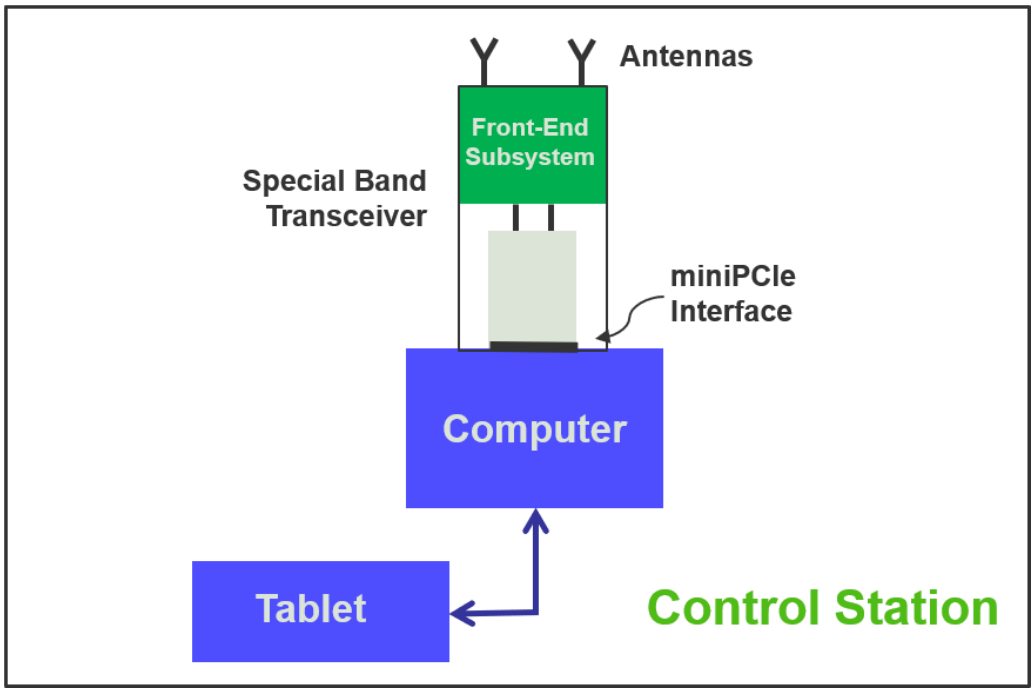
Appendix B – UGV with Industrial WiFi Transceivers





Appendix C – UGV with Special Band Transceivers





Appendix D – UGV with Front End Subsystems