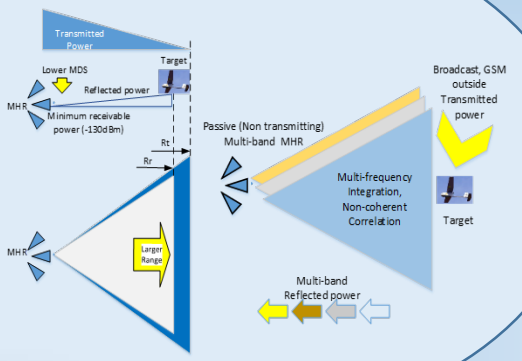
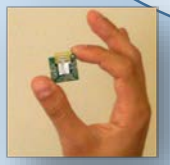
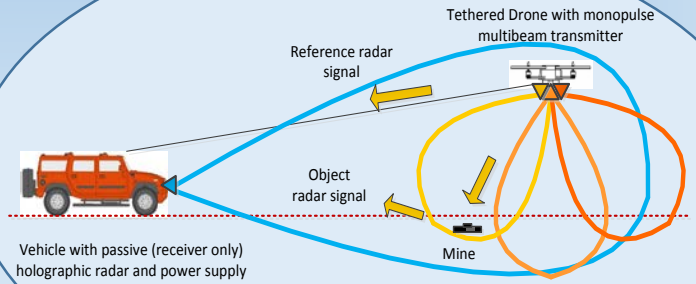
PASSIVE RADAR FOR SMALL UAS



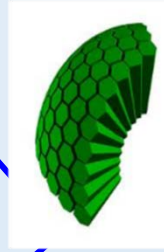


PLANAR MONOLITHICS INDUSTRIES, INC.
East Coast: 7311F GROVE ROAD, FREDERICK, MD 21704 USA • PHONE: 301-662-5019 • FAX: 301-662-2029
West Coast: 4921 ROBERT J. MATHEWS PARKWAY, SUITE 1, EL DORADO HILLS, CA 95762 USA • PHONE: 916-542-1401
EMAIL: sales@pmi-rf.com WEB: www.pmi-rf.com
ISO 9001 CERTIFIED

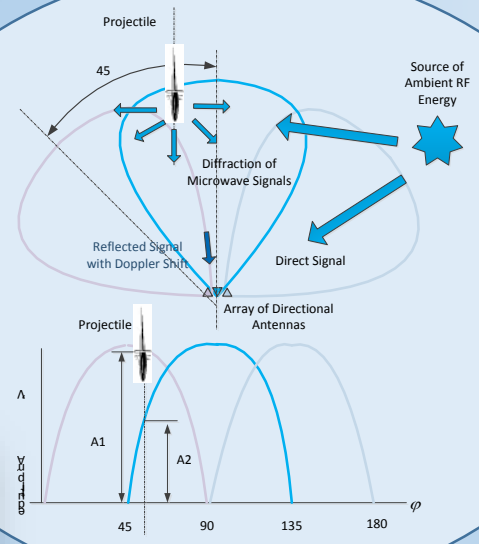
MINE DETECTION GROUND PENETRATING RADAR ON TETHERED DRONE



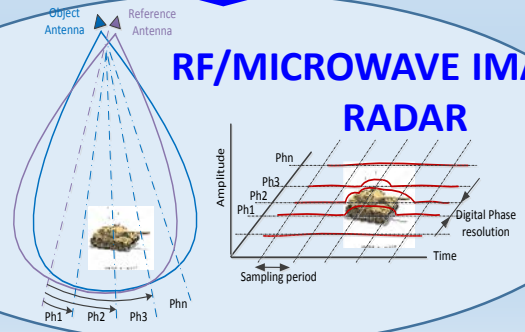
FLY EYE RADAR



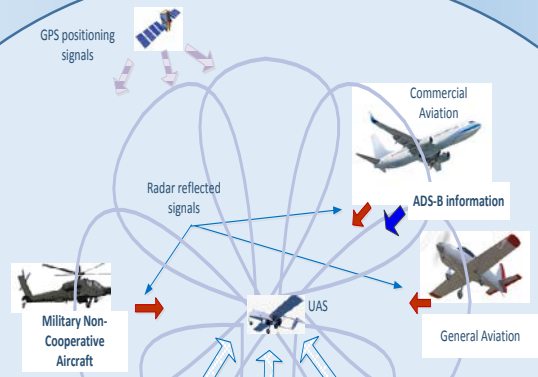
PASSIVE SMALL PROJECTILE TRACKING RADAR



RF/MICROWAVE IMAGING RADAR



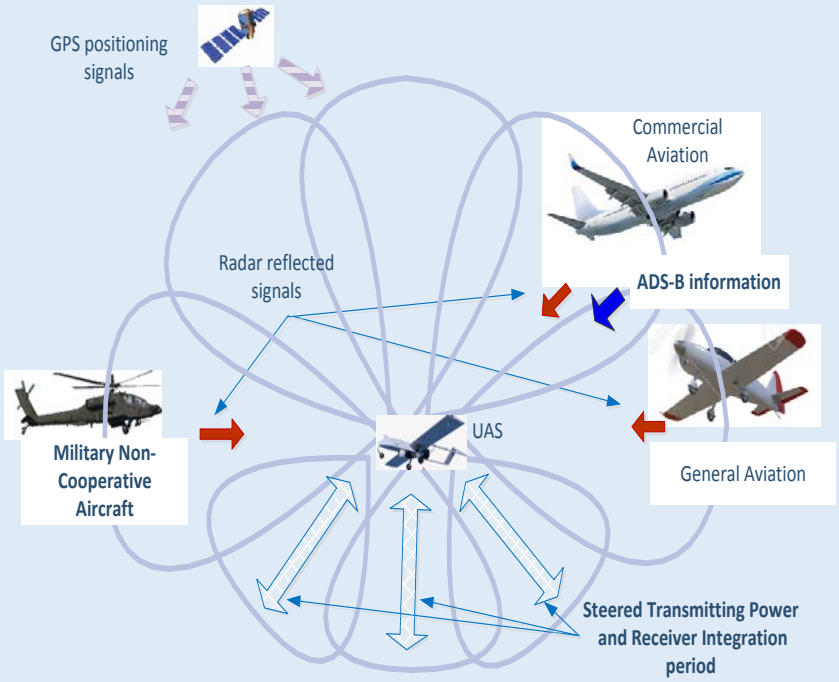
SENSE & AVOID RADAR FOR UAS



PLANAR MONOLITHICS INDUSTRIES, INC.
PMI East Coast: 7311-F Grove Road, Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
PMI West Coast: 4921 Robert J. Mathews Parkway, Suite 1, El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 916-265-2597
Web: www.pmi-rf.com Email: sales@pmi-rf.com

SENSE AND AVOID RADAR FOR UAS

Multibeam monopulse radar for Airborne Based Sense and Avoid (ABSAA) system concept:



- Multibeam monopulse radar with array of directional antennas is positioned on Unmanned Aircraft System (UAS). Radar signals simultaneously transmitted and received by multiple angle shifted directional antennas with overlap antenna patterns the entire sky, **360 degrees for both horizontal and vertical coverage.**
- Digitizing of signals in separate directional antennas relative to reference signals provides **high-accuracy high-resolution range and azimuth** measurement and allows to record real time amplitude and phase of reflected from **non-cooperative aircraft** signals.
- **High resolution range and azimuth measurement** provides minimal tracking errors in both position and velocity of non-cooperative aircraft and will be determined by sampling frequency of digitizer.
- **High speed sampling** with high-accuracy processor clock provides high resolution phase/time domain measurement even for wide Field of View (FOV) directional antennas.
- Fourier transform (**frequency domain processing**) of received radar signals provides signatures and dramatically increases probability of detection for non-cooperative aircraft.
- **Steering of transmitting power** and integration, correlation period of received reflected signals for separate antennas (directions) allows dramatically decreased ground clutter for low altitude flights.
- **Open architecture, modular** construction allows combination of radar sensor with Automatic Dependent Surveillance – Broadcast (ADS-B), electro-optic, acoustic sensors.

REFERENCES

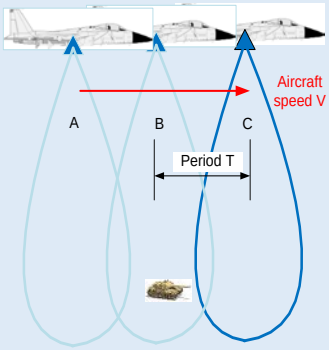
[1] A. Gorwara, P. Molchanov, O. Asmolova, Doppler micro sense and avoid radar, 9647-6, Security+Defense 2015, Toulouse, France, September 2015, (http://pmi-rf.com/documents/DopplerMicroSenseandAvoidRadarPaper.pdf).

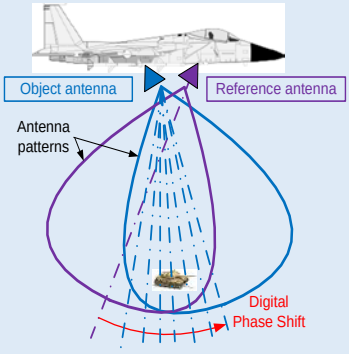
[2] P. Molchanov “All digital radar architecture.” Paper 9248-11, Security+Defense Conference, Amsterdam, September 25, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2060249).

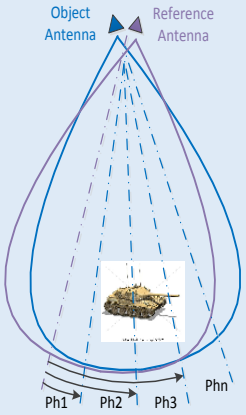
[3] P. Molchanov, O. Asmolova. “Sense and avoid radar for micro-nano robots (Invited Paper),” Security+Defense Conference, Amsterdam, September 24, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2071366).

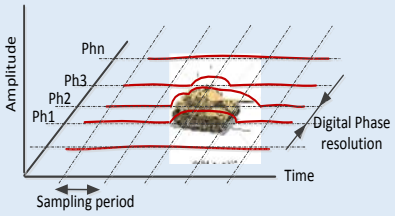
PLANAR MONOLITHICS INDUSTRIES, INC.
PMI East Coast: 7311-F Grove Road, Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
PMI West Coast: 4921 Robert J. Mathews Parkway, Suite 1, El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 916-265-2597
Web: www.pmi-rf.com Email: sales@pmi-rf.com

RF/MICROWAVE IMAGING RADAR









Technical Description

- Proposed new concept of RF/microwave imaging system will provide **all weather high-resolution imaging** with good **penetrating** of a foliage and even ground capability;
- Image **resolution** determined by processor and sampling frequency and do **not limited by diffraction**;
- **Non-scanning** monopulse system allows dramatically **increase imaging range** by integration 2-3 orders more signals than regular scanning systems;
- Proposed imaging system can **simultaneously** cover entire sky, 360 degree by azimuth and elevation for **multiple targeting**;
- Directional antennas can be close positioned or distributed in **small size** aperture and installed on small aircraft or **UAS;**

REFERENCES

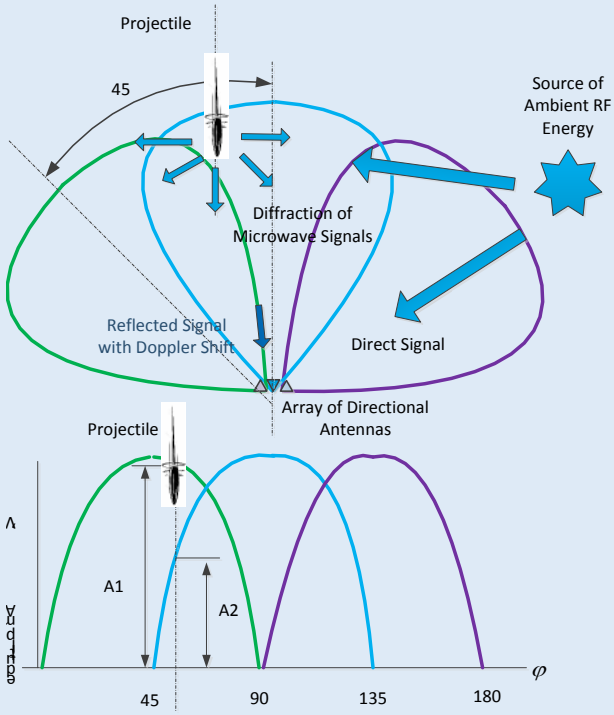
[1] A. Gorwara, P. Molchanov, O. Asmolova, Doppler micro sense and avoid radar, 9647-6, Security+Defense 2015, Toulouse, France, September 2015, (http://pmi-rf.com/documents/DopplerMicroSenseandAvoidRadarPaper.pdf).

[2] P. Molchanov "All digital radar architecture." Paper 9248-11, Security+Defense Conference, Amsterdam, September 25, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2060249).

[3] P. Molchanov, O. Asmolova. "Sense and avoid radar for micro-nano robots (Invited Paper)," Security+Defense Conference, Amsterdam, September 24, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2071366).

PLANAR MONOLITHICS INDUSTRIES, INC.
PMI East Coast: 7311-F Grove Road, Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
PMI West Coast: 4921 Robert J. Mathews Parkway, Suite 1, El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 916-265-2597
Web: www.pmi-rf.com Email: sales@pmi-rf.com

PASSIVE SMALL PROJECTILE TRACKING RADAR



There are lot of ambient RF/microwave sources: different kinds of communication, radar, navigation and datalink transmitters, and same time lot of moving with different size and speed objects are in battlespace. How passive **Doppler radar can detect small projectile** in so noisy battlespace? Small arms projectile has specific limited range of velocity which is relatively constant. Doppler frequency shift for small arms projectile and limited range of ambient RF/microwave sources lay in **specific narrow band** and can be used for arm fire location.

Array of directional antennas in passive radar will receive direct microwave signals from the ambient sources and reflected from objects part of these microwave signals. The radar signals reflected from moving with high speed projectiles will consist of a Doppler frequency shift in determined **narrow frequency band**. Application of bandpass filter with narrow bandwidth for Doppler signals will allow **dramatically increase signal/noise ratio** and detect small arms fire with high probability of detection.

REFERENCES

[1] A. Gorwara, P. Molchanov, O. Asmolova, Doppler micro sense and avoid radar, 9647-6, Security+Defense 2015, Toulouse, France, September 2015, (http://pmi-rf.com/documents/DopplerMicroSenseandAvoidRadarPaper.pdf).

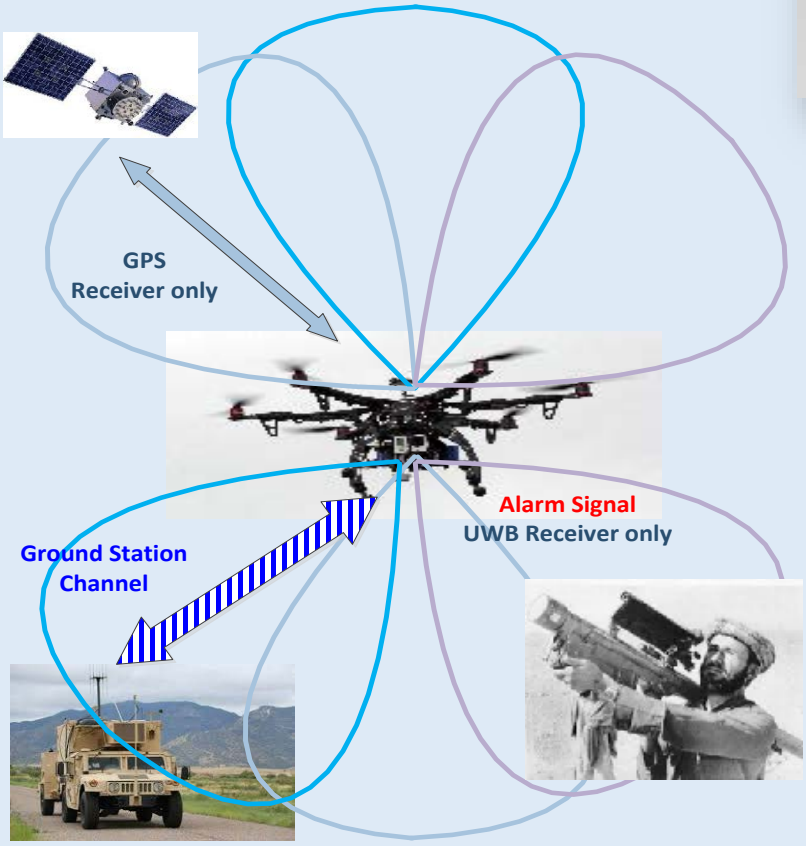
[2] P. Molchanov "All digital radar architecture." Paper 9248-11, Security+Defense Conference, Amsterdam, September 25, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2060249).

[3] P. Molchanov, O. Asmolova. "Sense and avoid radar for micro-nano robots (Invited Paper)," Security+Defense Conference, Amsterdam, September 24, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2071366).

PLANAR MONOLITHICS INDUSTRIES, INC.
PMI East Coast: 7311-F Grove Road, Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
PMI West Coast: 4921 Robert J. Mathews Parkway, Suite 1, El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 916-265-2597
Web: www.pmi-rf.com Email: sales@pmi-rf.com

PROTECTED COMMUNICATIONS

Multibeam Multifunction Antenna Array



First rule: If you want to protect transmitted information, do not transmit it in all directions. Transmit it only in the direction of your ground station or satellite connection

Second rule: Do not receive information from everywhere. It can be jammed or spoofed. Receive information only from your ground station or satellite. Verify direction to transmitter if possible.

Multibeam antenna array cover of the entire sky and can provide simultaneous **directional communication** with different sources: ground station or satellites. An array of directional antennas is phase independent and can be **multi-frequency, multifunction**. Digital interface provides simultaneous processing possibility. Monopulse processing of signals in two or a few directional antennas allows to find and **verify direction** to signal source.

REFERENCES

[1] A. Gorwara, P. Molchanov, O. Asmolova, Doppler micro sense and avoid radar, 9647-6, Security+Defense 2015, Toulouse, France, September 2015, (http://pmi-rf.com/documents/DopplerMicroSenseandAvoidRadarPaper.pdf).

[2] P. Molchanov “All digital radar architecture.” Paper 9248-11, Security+Defense Conference, Amsterdam, September 25, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2060249).

[3] P. Molchanov, O. Asmolova. “Sense and avoid radar for micro-nano robots (Invited Paper),” Security+Defense Conference, Amsterdam, September 24, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2071366).

PLANAR MONOLITHICS INDUSTRIES, INC.
PMI East Coast: 7311-F Grove Road, Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
PMI West Coast: 4921 Robert J. Mathews Parkway, Suite 1, El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 916-265-2597
Web: www.pmi-rf.com Email: sales@pmi-rf.com

NANO-DRONE WITH FLY EYE RADAR

- Non-scanning monopulse multi-beam (Fly Eye) micro radar will provide entire sky high-resolution, multi-target detection, tracking and recognition in **rain, snow smoke, fire conditions;**
- Non-scanning monopulse system allows for a **dramatic increase in radar range and recognition ability** by integration and smart processing of 2-3 orders more signals than any regular radar scanning system;
- Optional micro radar can be applied for **obstacle avoidance, mapping, navigation, thru wall, ground penetrating,** and **mine detection.**
- Detection and image resolution is determined by the processor sampling frequency and time accuracy and are **not limited by diffraction for small targets**;

REFERENCES

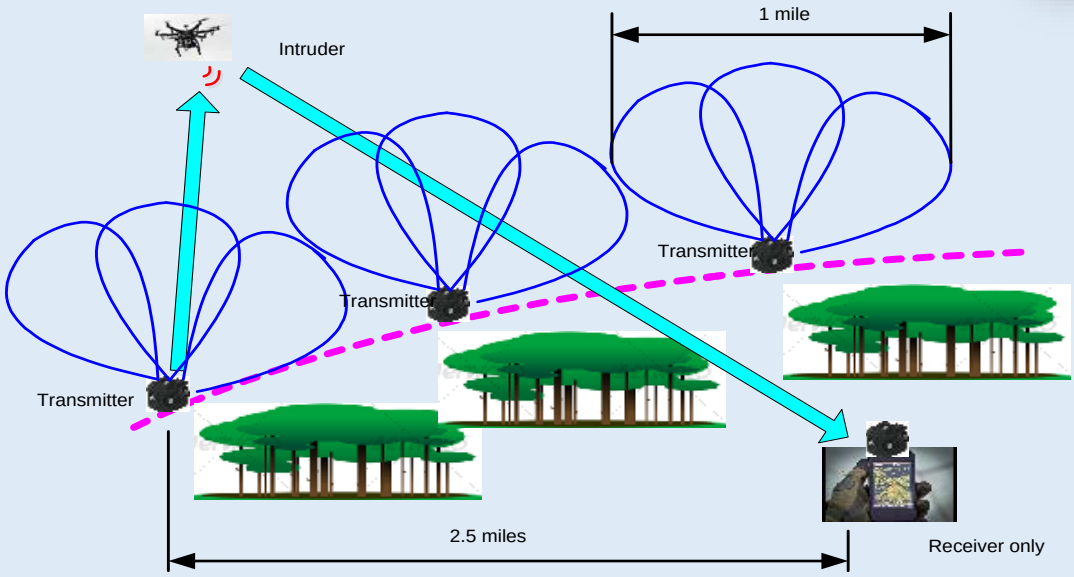
[1] A. Gorwara, P. Molchanov, O. Asmolova, Doppler micro sense and avoid radar, 9647-6, Security+Defense 2015, Toulouse, France, September 2015, (http://pmi-rf.com/documents/DopplerMicroSenseandAvoidRadarPaper.pdf).

[2] P. Molchanov "All digital radar architecture." Paper 9248-11, Security+Defense Conference, Amsterdam, September 25, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2060249).

[3] P. Molchanov, O. Asmolova. "Sense and avoid radar for micro-nano robots (Invited Paper)," Security+Defense Conference, Amsterdam, September 24, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2071366).

PLANAR MONOLITHICS INDUSTRIES, INC.
PMI East Coast: 7311-F Grove Road, Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
PMI West Coast: 4921 Robert J. Mathews Parkway, Suite 1, El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 916-265-2597
Web: www.pmi-rf.com Email: sales@pmi-rf.com

DISTRIBUTED RADAR FOR DRONE DETECTION



The concept of distributed (multi-static) radar is based on the application of **multiple illuminating (transmitting) devices** distributed along the perimeter of protected zone or surveillance area. Ultra-wide multibeam monopulse radar receiver with an array of the angle shifted directional antennas positioned at a safe distance. Radar signals simultaneously received by two or a few directional antennas are used for **high-accuracy high-resolution azimuth and range measurement.** Digitizing of signals in separate directional antennas relative to processor reference signals allows for high-accuracy real time amplitude and phase measurement and as a result, high resolution tagets tracking. Fourier transform (frequency domain processing) of received radar signals provides **signatures** and information not only about **shape**, but about **material of detected targets**.

REFERENCES

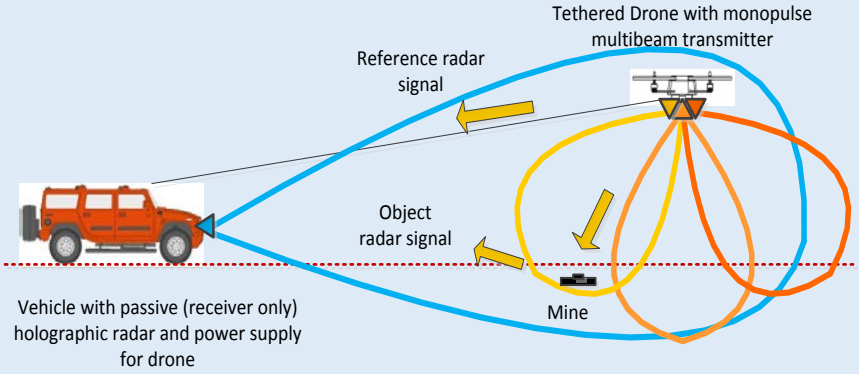
[1] A. Gorwara, P. Molchanov, O. Asmolova, Doppler micro sense and avoid radar, 9647-6, Security+Defense 2015, Toulouse, France, September 2015, (http://pmi-rf.com/documents/DopplerMicroSenseandAvoidRadarPaper.pdf).

[2] P. Molchanov “All digital radar architecture.” Paper 9248-11, Security+Defense Conference, Amsterdam, September 25, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2060249).

[3] P. Molchanov, O. Asmolova. “Sense and avoid radar for micro-nano robots (Invited Paper),” Security+Defense Conference, Amsterdam, September 24, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2071366).

PLANAR MONOLITHICS INDUSTRIES, INC.
PMI East Coast: 7311-F Grove Road, Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
PMI West Coast: 4921 Robert J. Mathews Parkway, Suite 1, El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 916-265-2597
Web: www.pmi-rf.com Email: sales@pmi-rf.com

MINE DETECTION, GROUND PENETRATING RADAR ON TETHERED DRONE



Proposed new bi-static ground penetrating radar concept with holographic imaging. **Low frequency waves** with **good ground penetration** allows decrease transmitter power up to **hundred milliwatt for one meter depth of exploration**. As result low frequency low transmitting power GPR transmitter can be positioned on small tethered drone and provide maximum targets cross-section. Ultra-wide band multibeam **monopulse radar** receiver with array of angle shifted directional antennas provides **high-accuracy high-resolution** measurement by application of reference beam. Digitizing of signals in separate directional antennas relative to processor reference signals allows to record real time **digital hologram** with amplitude and phase information about underground targets. Resolution of digital hologram and corresponding image **resolution will be determined by sampling frequency of digitizer** and not depends from radar beamwidth. High speed sampling with high-accuracy processor clock will provide high resolution of images even for low frequency radar waves. Holographic digital phase/time domain processing of received signals allows to **restore images** of detected objects. Fourier transform (frequency domain processing) of received radar signals provides signatures and information not only about shape, but about **material** of buried objects.

REFERENCES

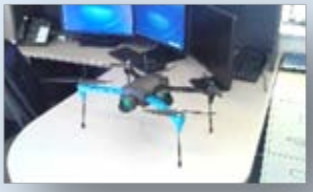
[1] A. Gorwara, P. Molchanov, O. Asmolova, Doppler micro sense and avoid radar, 9647-6, Security+Defense 2015, Toulouse, France, September 2015, (http://pmi-rf.com/documents/DopplerMicroSenseandAvoidRadarPaper.pdf).

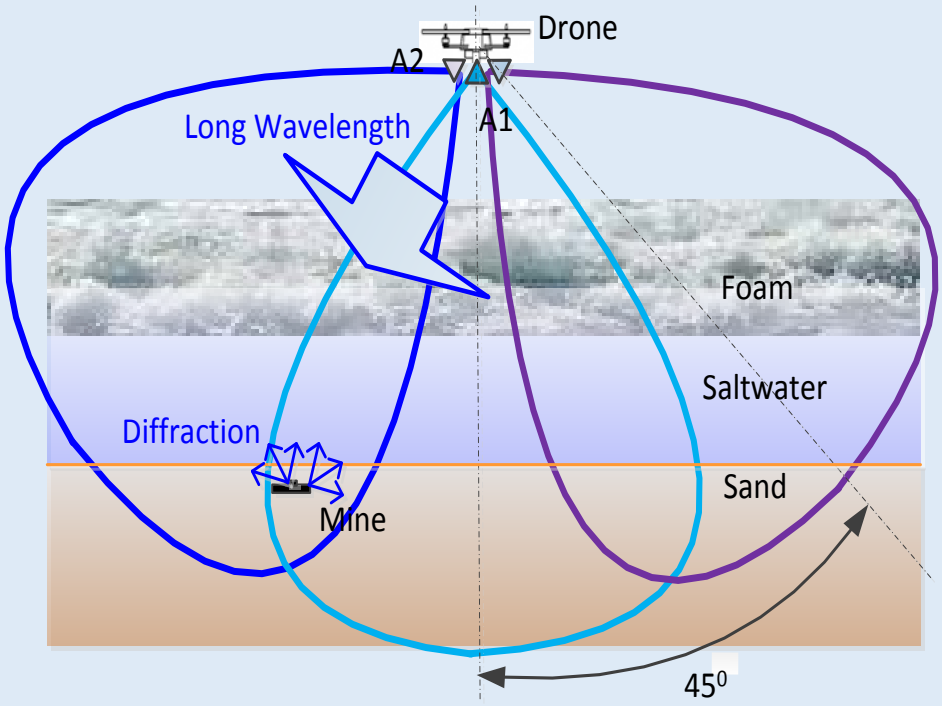
[2] P. Molchanov “All digital radar architecture.” Paper 9248-11, Security+Defense Conference, Amsterdam, September 25, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2060249).

[3] P. Molchanov, O. Asmolova. “Sense and avoid radar for micro-nano robots (Invited Paper),” Security+Defense Conference, Amsterdam, September 24, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2071366).

PLANAR MONOLITHICS INDUSTRIES, INC.
PMI East Coast: 7311-F Grove Road, Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
PMI West Coast: 4921 Robert J. Mathews Parkway, Suite 1, El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 916-265-2597
Web: www.pmi-rf.com Email: sales@pmi-rf.com

MINE DETECTION IN LITTORAL ZONE





- Proposed new concept of UAS based mine detection system will provide **high-resolution detection, recognition and imaging** with **up to 10' seawater plus 3' ground** penetrating and tolerant to foam and waves condition capability

- **Non-scanning** monopulse system allows dramatic **increase in imaging range and recognition ability** by integration and smart processing of **2-3 orders more signals** than any regular radar scanning systems

- Proposed system **multi-beam** and **multi-target**

- Detection and image **resolution** determined by processor and sampling frequency and are **not limited by diffraction** for small targets

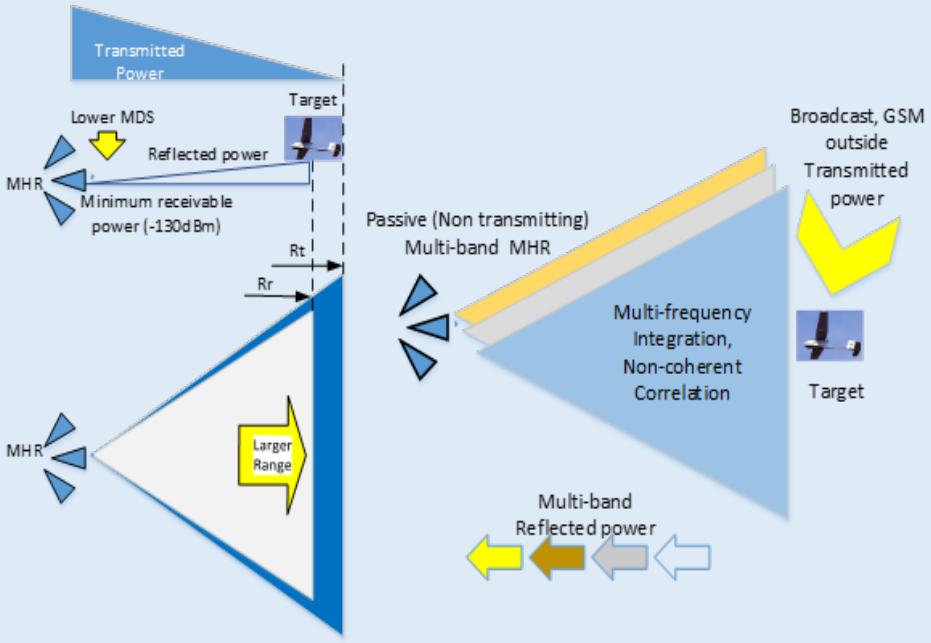
- Directional antennas can be closely positioned or **distributed** in **small size** aperture and installed on **UAS.**

REFERENCES

[1] A. Gorwara, P. Molchanov, O. Asmolova, Doppler micro sense and avoid radar, 9647-6, Security+Defense 2015, Toulouse, France, September 2015, (http://pmi-rf.com/documents/DopplerMicroSenseandAvoidRadarPaper.pdf).
[2] P. Molchanov "All digital radar architecture." Paper 9248-11, Security+Defense Conference, Amsterdam, September 25, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2060249).
[3] P. Molchanov, O. Asmolova. "Sense and avoid radar for micro-nano robots (Invited Paper)," Security+Defense Conference, Amsterdam, September 24, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2071366).

PLANAR MONOLITHICS INDUSTRIES, INC.
PMI East Coast: 7311-F Grove Road, Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
PMI West Coast: 4921 Robert J. Mathews Parkway, Suite 1, El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 916-265-2597
Web: www.pmi-rf.com Email: sales@pmi-rf.com

PASSIVE RADAR FOR SMALL UAS



Technical Description

Proposed new concept of passive monopulse RF sensor system provide **entire sky all-weather momentary** awareness and targeting capability.

- Monopulse **multi-beam** method provides simultaneous **high-accuracy ratio measurement** for **360 degree** by azimuth and elevation;
- Array of angular shifted directional antennas is not phase dependent and can be **multi-band** and **multi-function**;
- Directional antennas may be installed **closely** or **loosely distributed** over the perimeter of the carrier platform or between separate robotic carriers in swarm;
- **Receiving 2-4 orders more signals** than regular scanning systems provides 2-3 orders **longer passive radar range**;
- Directional antennas can be close positioned or distributed in **small size** aperture and installed on small aircraft or **UAS;**

REFERENCES

[1] A. Gorwara, P. Molchanov, O. Asmolova, Doppler micro sense and avoid radar, 9647-6, Security+Defense 2015, Toulouse, France, September 2015, (http://pmi-rf.com/documents/DopplerMicroSenseandAvoidRadarPaper.pdf).

[2] P. Molchanov "All digital radar architecture." Paper 9248-11, Security+Defense Conference, Amsterdam, September 25, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2060249).

[3] P. Molchanov, O. Asmolova. "Sense and avoid radar for micro-nano robots (Invited Paper)," Security+Defense Conference, Amsterdam, September 24, 2014, (http://spie.org/Publications/Proceedings/Paper/10.1117/12.2071366).