March 10, 2008

Federal Communications Commission
Office of Engineering and Technology
Experimental Licensing Branch
445 12th St., S.W.
Room 7-A322
Washington, DC 20554

To Whom it May Concern,

On behalf of ImSAR LLC I would like to apply for a Special Temporary Authority to further the development of a lower power radar system. The system transmits less than 1W peak power and will be operated on an occasional basis of a few times per month for roughly an hour each time it is used.

This request is comparable to similar systems that have been granted an STA[1] and an Experimental Radio Service License[2].

I hope the attached document has sufficient information to enable a favorable approval of an STA.

Sincerely,

Adam Robertson
NanoSAR Program Manager
510 W 90 S
Salem UT 84653
801-762-7263
adamr@imsar.com

[1] Refer to STA file number S-2353-EX-96

[2] Refer to Experimental Radio Service file number 0302-EX-PL-2004

Deleted: **ImSAR Report¶**
Printed September 2007¶
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NanoSAR™ – The First 1 lb SAR Yielding High Quality Imagery¶
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Ryan L. Smith: ryan@imsar.com¶
Logan C. Harris: logan@imsar.com¶
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Prepared by¶
ImSAR LLC¶
510 W 90 S¶
Salem, UT 84653¶
801-362-4807¶
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Approved for distribution among:¶
U.S. Department of Defense¶ ... [1]

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Abstract ¶
High performance SAR has previously been unavailable for use on most UAS systems due to cost, size, weight and power consumption. NanoSAR is a 1.5 lb SAR that currently consumes less than 10 watts of power making it the most economical high performance SAR to date. Its weight and size allows the use of other key sensors like EO and IR without forcing the operator to choose which payload to fly. The sensor ... [2]

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Purpose of radio operation:

ImSARs LLC has technology that is able to track moving targets, image the surface of the earth, create digital elevation maps, assist in search and rescue operations, and detect small changes in a scene, such as the movement of a vehicle. The US Navy, Army and Air Force have expressed interest in this technology. The size, weight, power, and cost of this Nano sized Synthetic Aperture Radar system (NanoSAR) is an order of magnitude less than similar systems. The radical change is weight and power consumptions enables tactical use of the radar, which in turn gives surveillance capabilities to small sets of soldiers that were previously unavailable. With the new surveillance capabilities, dangerous and life threatening situations can be further reduced.

Similar radar systems, such as Linx SAR weighs 85 lbs and transmit 300W of power. ImSAR's radar system weighs 2 lbs and transmits less than 1W of power. ImSAR requests a temporary authority in order to compete product testing and begin customer demonstrations.

ImSAR will use this STA to performed tests from a small aircraft flying under 2km in elevation. The transmit and receive antennas are nominally pointed toward the earth. Reflected signals are collected and processed to create images of the ground. The resolution of the imagery is directly proportional to the bandwidth of the signal transmitted. In order to obtain resolutions as small as 0.3 m, a transmit bandwidth of 500 MHz is desired. Transmission is linear frequency modulated continuous wave with the frequency being swept from the minimum to the maximum frequency 1000 times per second. Because the transmission power is under 1W and the frequency sweeps very rapid, the average power at a given frequency is extremely low.

Transmissions will be generally performed in remote areas over very limited time intervals of roughly an hour at a time, a few times per month.

Operation Location and Height:

NanoSAR will be operated from a small aircraft at a height between 0m and 5000m. The transmit signal is directed perpendicular to the line of flight toward the ground using a simple patch antenna array with a beam width approximately 45°x 10°. The peak of the antenna pattern has a 45° incident angle to the ground. The return signal is received by an identical receive antenna co-located with the transmit antenna.

Data collections will occur primarily over rural areas of northern Utah to test the functionality and demonstrate the utility of the NanoSAR as a tool for both commercial and military applications. Sites of interest will be imaged will be terrains of interest to potential customers.

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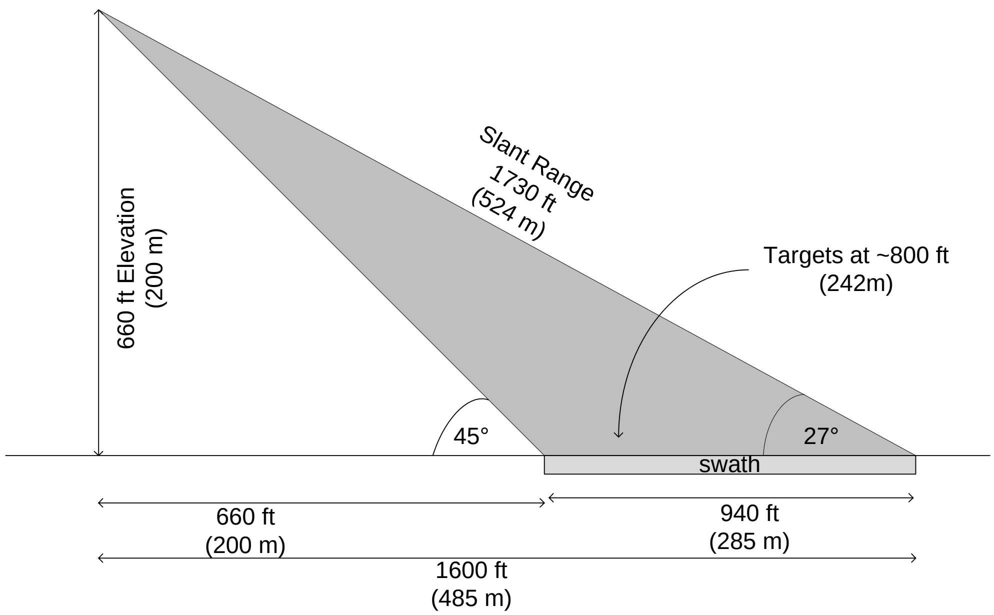

Description of the Transmit Signal:

The transmit signal is from 10 to 10.5 GHz. Most transmissions will be further constrained to a small bandwidth of 150 MHz from 10.325 to 10.475 GHz. The signal is continuous and modulated only by frequency. The frequency is ramped from the bottom of the bandwidth to the top of the bandwidth at a 1kHz rate. The received signal is mixed with the transmitted signal in a homodyne fashion. Frequency is controlled with a highly stable PLL and 25 MHz crystal with 25 ppm stability. The frequency ramp is controlled with a direct digital synthesizer capable of over 60 dB ACPR. The final power amplifier is a linear MMIC based amplifier with excellent linearity. The highest power spectral density we anticipated (75 MHz bandwidth), is -49 dBW/Hz.

We have equipment in house to measure out of band spurious signals and we regularly measure our transmission signals to minimize harmonics and spurious signals.

Time Period of Operation

We are preparing form 1494 for NanoSAR. We anticipate the 1494 to take at least 6 months for approval. Until that is complete, we would like to continue development. We anticipate doing tests a few times per month, with each test typically lasting under 1 hour.

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Note: All SAR images in this document are at 1 m resolution taken at 500 feet or greater elevation. The maximum range in the images is 750 m. These are engineering images and do exhibit a few artifacts and are produced using the real-time algorithm code base that does not utilize any hand tweaking of imaging parameters.¶
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UAS and SAR Capabilities¶
For many years radar has been used in manned systems to allow pilots to detect enemy aircraft that was undistinguishable with the naked eye. SAR was also used as early as 1960 to confirm target identification and position before a final bombing run was executed. Radar overcame weather and atmospheric obstacles such as smoke, sand storms, and shimmering heat waves that obscure or blur targets of interest. Radar also proved very useful because it inherently measures range with a high degree of precision, and SAR is capable of yielding geo-location to the same accuracy of the GPS system used to provide motion data for processing. Differential GPS can provide accuracies on the order of sub-meters and commercial WAAS enabled systems will generate accuracies less than 10m of error. ¶
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Radar also interacts strongly with ... [3]

ImSAR Report

Printed September 2007

NanoSAR^{TM} – The First 1 lb SAR Yielding High Quality Imagery

Ryan L. Smith: ryan@imsar.com
Logan C. Harris: logan@imsar.com

Prepared by
ImSAR LLC
510 W 90 S
Salem, UT 84653
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Insitu

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Abstract

High performance SAR has previously been unavailable for use on most UAS systems due to cost, size, weight and power consumption. NanoSAR is a 1.5 lb SAR that currently consumes less than 10 watts of power making it the most economical high performance SAR to date. Its weight and size allows the use of other key sensors like EO and IR without forcing the operator to choose which payload to fly. The sensor has an extremely low probability of detection and provides real-time or post-flight image processing. The system is designed for high volume manufacturing and is expected to be in full production in Q2 or Q3 of 2008. The NanoSAR product line has a very aggressive roadmap to also put it at the lead in SAR performance and capabilities by the end of 2010. NanoSAR has been developed by ImSAR with support from Insitu.

Page 3: [3] Deleted **Adam Robertson** **3/10/2008 4:54 PM**

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UAS and SAR Capabilities

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Radar also interacts strongly with metal and manmade objects as seen in the figure below. Because NanoSAR currently uses a horizontal polarization antenna, barbed wire fences in the rural area are strongly detected in the horizontal direction. The vertical fence lines can be detected by flying a box pattern around an area of interest or by using a dual polarization antenna. Houses and outbuildings appear bright as well as farm equipment and well casings. Manmade structures in natural environments are easily detected.

The SAR community has been growing rapidly over the past 20 years. Scientists in government, educational and commercial fields have advanced SAR capabilities to solve problems and answer questions in defense, geology, agriculture and archeology.

EO/IR/SAR Capabilities

SAR has been known in the past to produce imagery with coarse resolution and subsurface penetration. The interpretation of those images is sometimes referred to as “blobology”. Highly trained analysts are needed to decipher features within the images, making SAR unappealing to small forces. This is still the case today with most SAR data used by the military. The challenge lies in making SAR images understandable to one who has little or no training.

SAR is most useful when used in conjunction with EO/IR cameras. SAR provides extra capabilities but does not replace the EO/IR sensors. That is why a SAR sensor must be small and light enough to be flown with an EO/IR sensor suite even on small UAS such as the ScanEagle. The pros and cons of each sensor technology are illustrated in the following table.

Sensor	Pro	Con
SAR	• Wide Field of View • All Weather • Accurate Geo-Location	• Lower Resolution • Hard to Interpret • Snap-shots
EO	• High Resolution • Easy to Understand • Video	• Day Use Only • Blocked by Rain, Snow, Sand, Fog • Inaccurate Range
IR	• Medium Resolution • Video • Night Use	• Blocked by Rain, Snow, Sand, Fog • Inaccurate Range

If all sensors are carried at the same time then the sensors can be synergistically used together to accomplish the mission. Here are some examples:

Mission: It is nighttime and a downed aircraft needs to be located in a remote area.
Use SAR to scan a wide area to **detect** manmade objects.
When a bright object is detected in the SAR image, associated geo-location data is used to cue an IR or low light camera to **identify** the object.

Mission: There is a dust storm and insurgents are suspected to be planting IEDs along a road way.
Scan roadway with SAR looking for vehicles along the road.
Once a vehicle is **located** alert ground troops to investigate.

Mission: Provide continuous surveillance of a large area 24/7.
Scan area with SAR to **detect** changes in the area.
Once a change is detected, focus in on the area with EO/IR for **identification.**

Mission: Locate a vessel on open water while atmospheric conditions are poor.
Scan large area with SAR to **detect** a manmade object on the ocean.
Once something of interest is detected, fly in closer to that area and use EO/IR for **identification.**

In each of these examples the sensors worked together to perform the mission.

This is similar to how the sensor suite on the Global Hawk has been used. On the Global Hawk the imagery used has been 50% SAR, 25% EO and 25% IR. The emphasis on SAR over EO and IR is due mainly to the ranges involved and issue of cloud cover, but demonstrates the necessity of SAR depending on the conditions.

ImSAR views the use of radar as enhancement to UAS sensor capabilities so that when EO and IR fail, radar fills in the gap. SAR images at higher resolution become more "photographic" but still require a new perspective to understand. Untrained individuals are able to identify many of the features in images once they understand that metal objects look the brightest in a SAR image. The images below are of a National Guard post with Humvees and engineering equipment lined up. SAR in these images could be used to identify whether a vehicle had come or gone. Light poles, bridge flashing, and air conditioning units on buildings are all noticeable as well.

The Lightweight Advantage

Because of the diverse range of payloads now being required by UAS, weight has become the top priority in the list of requirements for competing sensors. UAS range in payload capacities from a few ounces to hundreds of pounds, with the majority of the market capable of carrying several pounds or more. A radar sensor in the 1 lb range and an approximate 10 W power consumption has small or negligible effect on the weight and power budgets of these systems. The NanoSAR currently weighs 1.4 lbs which includes the antenna, RF, real-time processor, 32 GB data storage and the motion sensor comprising GPS, IMU and motion processor. Simply put, you can add radar to your system and have enough room for other critical payloads particularly in systems the size of the ScanEagle. NanoSAR products will also replace legacy radars and make room for new and expanded capabilities.

Low Probability of Detection

Radar is an active sensor providing its own illumination, making it a source of detection for enemy forces. NanoSAR uses FMCW technology where the peak transmit power is significantly reduced and the RF signal is rapidly modulated over a wide bandwidth making the signal very difficult to detect. NanoSAR is currently transmitting less than 30 mW of power, and at ranges up to 8 km it is expected to only transmit 2 W.

Real-time Image Processing

Images can either be processed in real-time on board and stored onboard the solid state drive in JPEG format, or raw data may be collected to the drive for post-flight processing. The JPEG images are viewed over a NTSC video link using a DVR style toolbar that allows the user to view the most current data a with no zoom or to pan and zoom within the entire stored JPEG data set. Images may download off the platform once on the ground using a high speed data link.

Current SAR Imagery Analysis

Ground troops need to have images and data that quickly provides the information they need for a given task. Contrast change detection and natural environment detections are several ways that current NanoSAR images and data can be used more effectively by non-trained or low level trained personnel. Contrast change detection is performed by registering temporal displaced images spatially and then mapping each time map to a separate RGB color. Differences in time appear as a separate color.

Natural environment detections are easily discerned because of the sharp contrast between the scene and manmade objects like maritime vessels, boat wakes, downed aircraft, vehicles, ditches, ruts, wires, and buildings. The image below is of a rural community with wire fences, buildings, farm machinery, ditches and crops. In a more natural environment these features would be highly visible in scene.

Post-Flight Processing

High precision imagery may also be obtained by either collecting raw data on board or relaying data through a high bandwidth digital communications link to a ground station. The ground station uses more advanced algorithms able to run on high end work stations to produce and store high precision imagery and perform post compression analysis such as contrast change detection, image mosaicing, and speckle reduction.

High Volume Production

Founders at ImSAR were responsible for the setup and management of production at Wavetronix, a high volume traffic radar manufacturer. Full production is expected to begin in Q2 or Q3 of 2008 with capabilities of hundreds or thousands of units per year.

Roadmap

The NanoSAR short term roadmap includes an electronically scanned array, automated change detection, extended range to 4 km and then 8 km, spotlight SAR, Circular SAR, motion target indicator based on SAR, and a Ku Band – 4” resolution SAR. The long-term roadmap includes Interferometric SAR, foliage and ground penetrating radars and coherent change detection all targeted to be in the 1 lb weight class of radars.

Each of these advancements shift the difficulty of interpretation into algorithms and systems and away from the operator. Some of the longer range products may be developed sooner as the length of time for each development and schedule is susceptible to change due to funding resources and needs of the customers. The development schedule is aggressive, but is based on ImSAR’s past experience in quickly developing complicated radar systems. ImSAR is requesting funding from DoD agencies to aid in the development of the NanoSAR product line.

Year	2008		2009		2010		2011	
Development	Q1-2	Q3-4	Q1-2	Q3-4	Q1-2	Q3-4	Q1-2	Q3-4

Schedule							
Electronic Scanned Array	X	X					
Automated Contrast Change Detection	X	X					
Range Extension to 4, 8 km	X	X	X				
Spotlight		X	X				
CirularSAR		X	X				
Ku 4” resolution	X	X	X				
MTI – SAR Gradient		X	X				
Interfererometric SAR – DEMs			X	X			
FOPEN, GPEN				X	X		
Coherent Change Detection						X	X

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Specifications

Range Current – 1km, Q4 of 2007 – 2km

Resolution	14 inch
Weight	1.5 lbs
Power Consumption	< 10 Watts
Transmit Power	14 dBm
Communications	RS232, RS485, Ethernet 100MB/s, NTSC
Data Storage	32 GB Solid State
Processing	Real-time or Post-Flight
Antenna Type	Fixed Fan Beam 10 x 90 degrees
Antenna Polarization	Horizontal

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