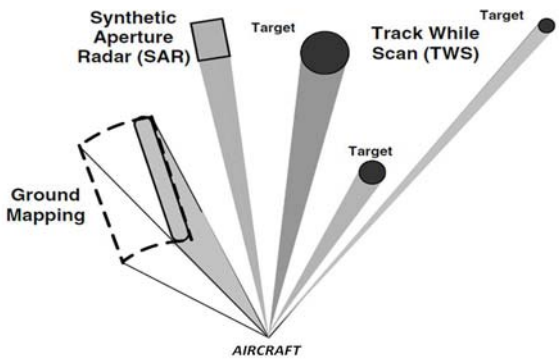
December 22, 2010
Authors: Rick Reaser,
Igor Mikhaylov

Information Paper

Application and Bandwidth Justification of Multi-Mission Radars under WRC AI 1.21

The radiolocation system envisioned in IWG XXX Proposal for WRC AI 1.21 is multi-mission radar capable of many functions, as shown in the Figure 1.

Figure 1
Multi-mission SAR



SAR High-Resolution Performance:
The evolution of Synthetic Aperture Radar (SAR) is towards high-performance real-time light-weight extremely-fine resolution imaging, with a user interface that might best be described as for a digital radar camera. These systems would include the ability to be pointed and operated over a wide range of 'pan' angles and 'tilt' angles. In SAR radar this would be described as squint and depression angles. The requirement to efficiently form images over such a large range of geometries has a profound impact on the design of a SAR system. Ideally, image formation algorithms would not suffer any performance degradation even for a sizeable depression angles and non-broadside squint angles. In the past, forming high-quality SAR images at sizeable non-broadside squint angles has been difficult, and more so at finer resolutions. Much of this difficulty can be mitigated with proper real-time motion compensation, that properly considers the radar-to-target geometry changes during a synthetic aperture, and collects data on the proper grid in Fourier space (the space in which the 3D Fourier transform of a SAR image is defined). Image formation is then considerably simplified. The penalty for easy image formation is the requirement for highly accurate and precise waveform control, both for the transmitted signal, and the local oscillator de-chirping signal. In general we need to control phase, frequency, and chirp rates to compensate for antenna phase-center motion. The net result is that the pulse-to-pulse frequency and bandwidth will change over the course of an aperture, further resulting in an expansion of the total RF bandwidth required of the hardware, increasing possibly considerably beyond that for any single pulse. This is one reason why the additional 300 MHz spectrum is needed. The other reason the spectrum is needed is the ability of the larger chirp spectrum to provide better slant range resolution.

For Synthetic Aperture Radar (SAR) the conventional rule-of-thumb is that the slant range resolution for a given Chirp bandwidth, for a single pulse, is the 1.2*speed of light divided by 2* Chirp bandwidth. The 1.2 value accounts for the typical compressed pulse window function and sidelobe control. For an increase of 300 MHz in the chirp bandwidth the slant range resolution improvement is about 16%. In

addition to the slant range resolution improvement, we can now use the 300 MHz of additional spectrum to compensate for aircraft motion. This is very important for this SAR radar performance.

ISAR Performance:
Unlike imagery that is produced by SAR mode, imagery in Inverse Synthetic Aperture Radar (ISAR) depend on data generated from reflectivity of the target as the target rotates within radar beam's boundaries. Radar performance bandwidth needs to be increased by accommodating for angular rotation rate constant, required bandwidth = speed of light * angular rotation rate of the target *pulse width / wavelength.

Complex Modes and Target Characteristics:
Wider bandwidth allows for increased information regarding target's presence, location and physical characteristics. In order to process multiple target characteristics, a reflectivity data in more than one dimension needs to be collected. Wider bandwidth allows radar to collect reflectivity data vs. range delay, viewing angle and frequency.

Complex radar modes such as Micro-Doppler radars, small moving parts on a stationary target require large amounts of bandwidth. In order to detect slight changes in speed of a small rotating object a complicated multi-chip Phased Coded modulation (i.e. Barker Codes) needs to be employed. For these types of modes, rise and fall times are critical parameters, if they are too large a significant amount of chips describing miniscule Doppler shifts maybe lost.

Noise
Wider bandwidth reduces radar effects of external interference, such as rain, mist, various kinds of aerosols present in atmosphere, present metallic reflectivity.

Target Cross Section
For a signal with a wide bandwidth, target's scattering cross section becomes a time function. The target scattering cross section for radar with a wide bandwidth will be larger, than that with a narrower bandwidth signal. This means that the secondary directional pattern of a target will not have nulls arising and causing interference of waves reflected from different target elements. This allows for a more reliable and stable reception of reflected signals.

Economical Hardware
Wider bandwidth means lower average power for a signal and smaller duty cycle. This allows for cheaper, easier, lighter and more compact system development.

References:

1. Armin Doerrya, "Bandwidth requirements for fine resolution squinted SAR", Sandia National Laboratories, March 20, 2000
2. Armin Doerrya, and Doug Bickel "A 3-D SAR approach to IFSAR processing", Sandia National Laboratories, March 20, 2000
3. Taylor, James D. *Ultra-Wideband Radar Technology.* Florida: CRC Press LLC, 2001
4. Wehner, Donald R. *High-Resolution Radar - 2nd. ed.* Boston: Artech House , INC., 1995