Company and Technology Background

IMSAR LLC has radar 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. Various branches of the US military, including the Navy, Army, and Air Force, as well as some commercial businesses, have expressed interest in this technology. The size, weight, power, and cost of IMSAR's Synthetic Aperture Radar (SAR) system, known as NanoSAR, are an order of magnitude less than similar systems.

IMSAR performs SAR tests from a small aircraft typically flying between 2,000 and 10,000 feet in altitude (above ground level). Directional transmit and receive antennas are nominally pointed toward the earth. Reflected signals are collected and processed to create images of the ground. Transmission is a linear frequency modulated continuous wave (LFM-CW), or a "chirp," with the frequency being swept from the minimum to the maximum frequency 1000 times per second. A chirp signal is illustrated in Figure 1. Because the transmission sweeps are very rapid, the average power at any given frequency is extremely low, as is the likelihood of detection by (i.e., interference to) ground based systems operating in the same frequency range.

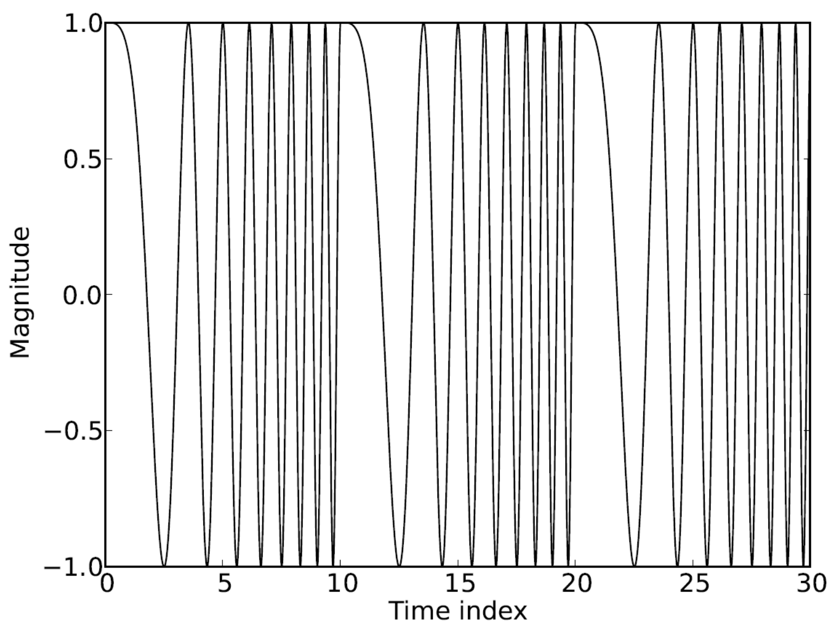

Figure 1. Example LFM chirp signal, increasing in frequency from left to right, then repeating.

UHF/UWB frequencies are employed to enable ground penetration and observation of specific targets where UHF/UWB reduces the clutter of the background. The transmit signal is directed perpendicular to the direction of travel and towards the ground using a directional antenna. The antenna radiation pattern is approximately 120° in elevation and 70° in azimuth. The back lobes of the antenna are attenuated significantly. The peak of the antenna pattern has a 45° incident angle to the ground. The return signal is received by the same antenna. An example of the geometry of a SAR is shown in Figure 2.

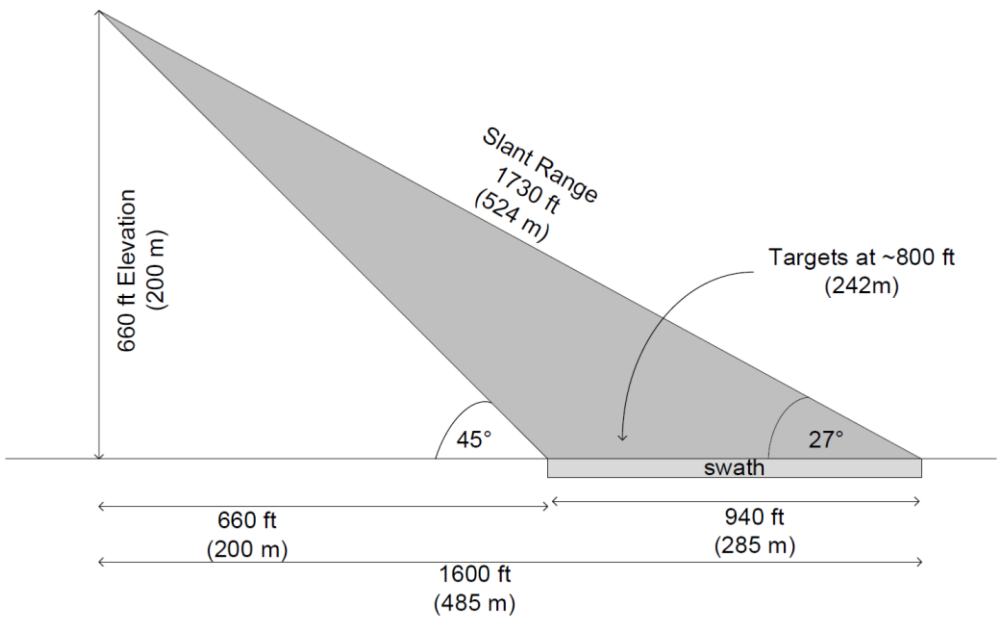

Figure 2. Example SAR geometry, from an airborne platform.

<u>Non-interference – Mathematical</u>

IMSAR's UHF band radar has a very low probability of interfering with other systems operating in the same frequency band, because the low-power signals are transmitted from a considerable range and are spread out over a large bandwidth.

The radar signal is a linear frequency modulated (LFM) "chirp" whose instantaneous frequency increases linearly throughout the duration of the radar pulse, beginning at the smallest frequency and ending at the largest. This is repeated 1000 times per second. Since each individual frequency is only transmitted for a very short duration, the power in each frequency bin is considerably less than it would be with a continuous wave (CW) signal transmitting at that single frequency. This is known as a spread spectrum signal.

As a microwave signal radiates from an antenna it spreads out as the distance from the antenna increases. This is in contrast to a laser beam, which is highly focused and maintains all of its power in the pointed direction. The power density (in units of watts per square meter) of a microwave signal radiated from an isotropic source decreases by a factor of $4\pi R^2$, where R is the distance from the antenna. For a directional antenna, the transmitted power is first multiplied by the gain of the antenna before dividing by the R^2 term. Even still the R^2 term becomes large very quickly and greatly reduces the power incident on the distant target.

The IMSAR UHF radar transmits through an antenna that has about 6 dBi of gain, currently operates over 560 MHz of bandwidth (from 400-960 MHz), and typically operates at a range of 3000 feet or more from the intended target. So the power gets spread out over the band and then the power density is reduced by the distance that it must travel before reaching the ground. The end result is that the transmitted radar signal is indistinguishable from noise once it reaches another device or system operating in a sub-band, such as the 11 MHz-wide bands used by the FirstNet emergency responders network (power levels are on the order of picowatts). (IMSAR is able to detect this signal from out of the noise with the use of a broadband receiver and appropriate signal processing techniques.)

Calculated Incident Power as a Function of LOS Distance to Receiver

The incident power level decreases with distance between the transmitter and receiver. Figure 3 shows the power level incident at a receiver system as a function of the distance of that system from the IMSAR UHF radar. The vertical line in the plot represents the minimum altitude (AGL) at which the UHF radar can successfully operate. At this "worst case" distance, and for a receiver bandwidth of 10 MHz, the incident power level is estimated to be about -65 dBm, or 320 picowatts. For a system with a smaller receiver bandwidth, the incident power would be even less.

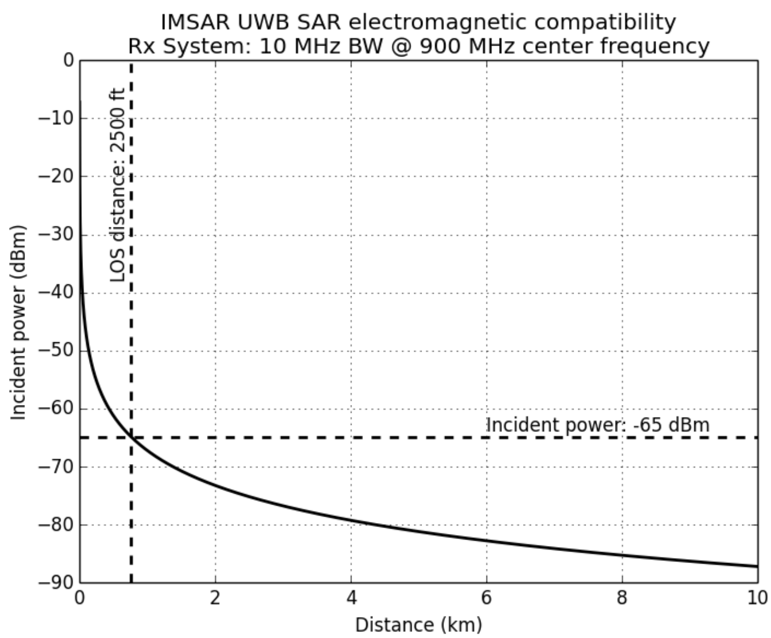

Figure 3. Power incident at a receiver as a function of distance from the UHF radar.

The results of Figure 3 were obtained using the following calculations.

Definitions

rr	ramp rate (Hz/sec)
duty	transmitter duty cycle
B_{Tx}	transmitter bandwidth (Hz)
B_{Rx}	receiver bandwidth (Hz)
P_{Tx}	transmit power (W)
P_{Rx}	receiver power (W)
G_A	transmit antenna gain (linear)
PRF	pulse repetition frequency (Hz)
freq	receiver frequency (Hz)
dist	distance to receiver (m)
FSPL	free space path loss
λ	wavelength (c/freq, where c is speed of light 3e8)

Equations

$$\mathrm{rr} = \frac{\mathrm{B_{Tx}\ PRF}}{\mathrm{duty}}$$

$$\mathrm{FSPL} = \left(\frac{4\pi\ \mathrm{dist}}{\lambda}\right)^2 = 20\log_{10}(\mathrm{dist} * \mathrm{freq}) + 20\log_{10}(4\pi\mathrm{c})$$

$$\mathrm{P_{Rx}} = \frac{\mathrm{B_{Rx}\ P_{Tx}\ PRF\ G_A}}{16\ \mathrm{rr}}\left(\frac{c}{\pi\ \mathrm{dist\ freq}}\right)^2$$

Example

duty	0.63
B_{Tx}	560 MHz (covering 400-960 MHz)
P_T	6 W
G_A	4
PRF	1000 Hz

For a receiver with 10 MHz bandwidth centered on 900 MHz, at 762.2 m (2500 ft) from the transmitter, the power level incident at the receiver is calculated to be 320 pW, or -65 dBm.