Estimating RFI Levels Due to Air Surveillance Radar

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February 14, 2002

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1 Introduction

This note addresses the expected power and interference-to-noise ratio (INR) for an airborne or space-based radiometer due to air surveillane radar. The expected power at the antenna terminals of the radiometer is given by:

$$P_R = \alpha G_T G_R \left(\frac{\lambda}{4\pi R} \right)^2 P_T \tag{1}$$

where P_T is the transmit power measured at the terminals of the radar antenna, G_T is the main beam gain of the radar antenna, α is a factor accounting for pattern loss due the location of the radiometer with respect to the radar main beam (i.e., $\alpha = 1$ for main beam, $\alpha = 0$ for a null), G_R is the gain of the radiometer antenna, λ is wavelength, and R is range. Note that for very directive antennas, α tends to be upper-bounded around G_T^{-1}; i.e., directive antennas tend to have isotropic gain far from the main beam.

The expected noise power at the antenna terminals of the radiometer is:

$$N_R = k(T_{scene} + T_{sys})B \tag{2}$$

where k is Boltzmann's constant (1.38×10^{-23} J/K), B is bandwidth, T_{scene} is the antenna temperature attributable to the observation, and T_{sys} is the effective system temperature. The INR is simply P_R/N_R.

2 INR Considerations

In a bandpass-digitizing receiver, we would like the INR to be less than the maximum quantization signal-to-noise ratio (QSNR) of the A/D. This allows both the interference and the "$T_{scene} + T_{sys}$" noise to be digitized without clipping. The rated QSNR of the 8-bit AD9054A (our current preference) is 45 dB. To determine if this is adequate in the presence of radar, consider the following scenario:

- Radar: ARSR-4 [1].

  $P_T = 60$ kW, peak

$G_T \approx 35$ dB

Frequency range: 1.2 GHz to 1.4 GHz; $\lambda = 21$ cm assumed

- $T_{scene} = 100°$K.
- Radiometer:

  $G_R = 3$ dB

  $T_{sys} = 400°$K.

  $B = 100$ MHz.

Figure 1 shows the resulting INR as a function of range when the radiometer is in the main beam, and when it is in the far sidelobes. Note that if the radiometer is in the far sidelobes, we become INR-limited when the range is less than 50 km. This may be a problem for airborne systems, and suggests that any scheme other than blanking may be ineffective under these conditions.

If the radiometer is in the main beam, we become INR-limited when the range is less than about 2000 km. This assumes line of sight (R^2) propagation, so the range may actually be significantly less for airborne radiometers, depending on altitude. Since the radar is nominally searching for aircraft (usually by rotating the beam), we should nevertheless expect that the radiometer will be INR-limited some percent of the time; specifically, as the radar is sweeps past the airborne radiometer. Since the beamwidth of the ARSR-4 is about 2°, the radiometer will be in the main beam about 0.6% of the time. The resulting loss of integration time (assuming blanking) should not be a problem.

Space-based radiometers will always be more than 10 km when in the far sidelobes, but could possibly be within 2000 km while in the main beam under certain rare circumstances.

This assessment should be similar for other radars, unless P_T is significantly greater. [1] identifies a 2.8 GHz radar, the ASR-9, for which $P_T = 1.1$ MW. If such a radar were operating in our bandwidth of intertest, that would be a 13 dB increase in INR, which would move our threshold of INR-limited range for operation

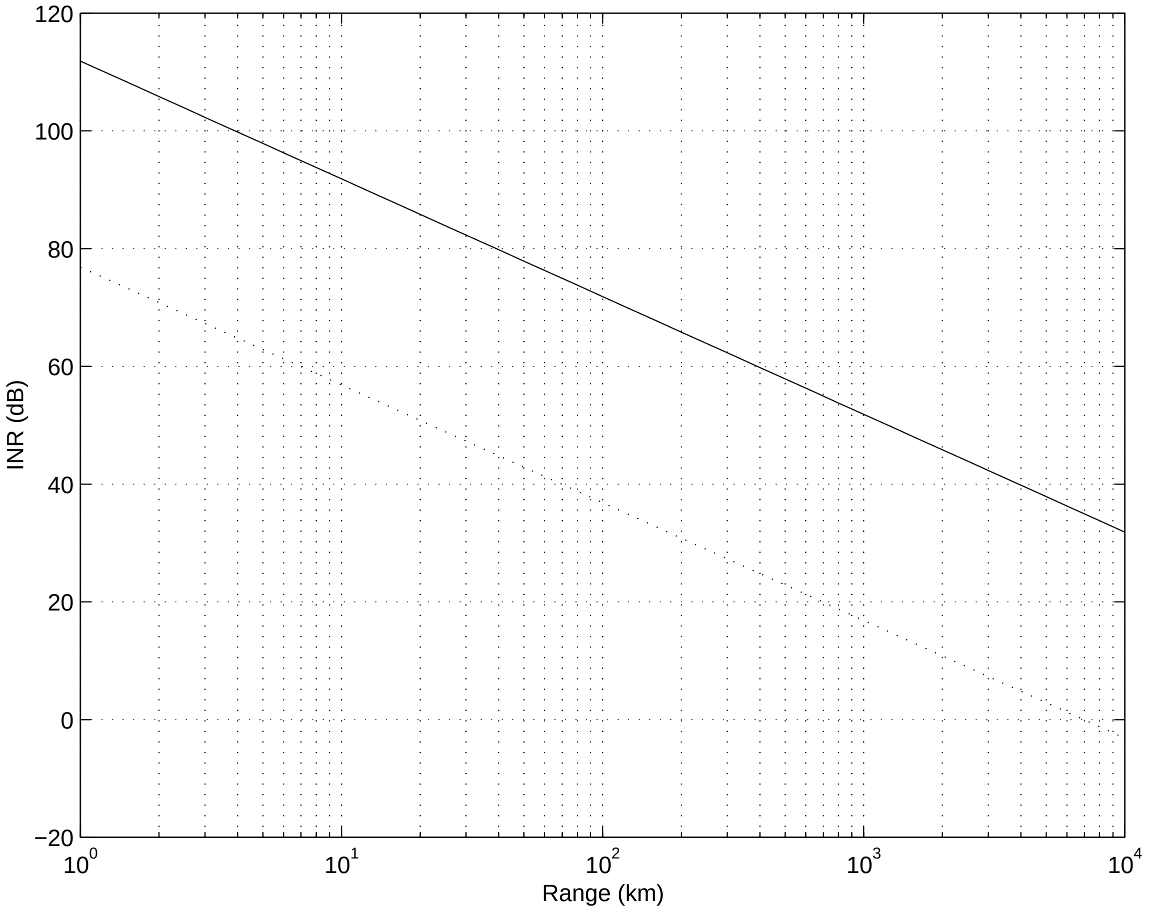

Figure 1: Expected peak INR. *Top Curve:* Radiometer in main beam ($\alpha = 1$). *Bottom Curve:* Radiometer in far sidelobes ($\alpha = G_T^{-1}$).

in the far sidelobes from 50 km to about 200 km, and so is probably not that much different.

3 Power/Linearity Considerations

A second consideration in designing a receiver to operate in a strong RFI environment is linearity. The concern is that if P_R is too large, the receiver may actually be driven into compression. In the example presented in the previous section, the N_R turns out to be about -92 dBm. Thus, we become INR-limited when $P_R \approx -47$ dBm. This is well below the achievable 1-dB compression point, which is on the order of -20 dBm even for systems with very low T_{sys}.

Further, this analysis suggests that the analog section of the receiver (antenna terminals through A/D input) should have a gain of about 47 dB, in order to achieve a nominal 0 dBm at the A/D input at the point at which we are about to exceed our maximum supportable INR. In an interference-free condition, this puts the (noise-only) signal power at the A/D input at -45 dB. It may be wise to switch to a 10-bit A/D to ensure that at least two bits of the A/D are being used in this case.

In the event that the radiometer is operating close to the radar; say, $R = 50$ km, and happens to be illuminated by the main beam, P_R could be as high as -13 dBm assuming the ARSR-4 P_T of 60 kW. This is unlikely to damage the receiver, but it may be prudent to include an analog blanking switch to reduce the recovery time from exposure to such a pulse.

4 Summary/Recommendations

Under the conditions considered above, a digital receiver with 47 dB gain followed by an 8-bit A/D (assuming 45 dB QSNR) should be sufficient to operate without clipping or compression, as long as the radiometer is more than 50 km from the radar. A safer approach may be to use a 10-bit A/D, to ensure that the $T_{sys} + T_{scene}$ noise toggles at least 2 bits of the A/D. Main beam illumination is does not seem to be a problem, as long as an analog blanker is available to reduce the receiver recovery time for strong pulses.

References

[1] M.E. Weber, "FAA Surveillance Radar Data as a Complement to the WSR-88D Network" (downloaded from http://www.gb.nrao.edu/˜rfisher).