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Interference from Vehicular Radar and CARMA Site Selection

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ABSTRACT

Vehicular radar may produce substantial radio frequency interference for millimeter observatories. The FCC has recently approved the use of the 24 GHz band for this purpose. The radars present a danger in both the fundamental and harmonic frequencies. FCC emission limits correspond to an 0.6 MJy source at a distance of 1 km. Careful site selection can significantly mitigate these effects.

1. Vehicular Radar

The Federal Communications Commission has recently issued an order permitting the operation and marketing of several new devices using ultra-wideband (UWB) technology (FCC 02-48). This is a revision of the Part 15 regulations. Vehicular radar at 24 GHz is among the technologies included in this order. In the past, the FCC has considered the implentation of vehicular radar at 47, 60 and 76 GHz. The current order does not exclude the possibility of future implementation at other frequencies. In fact, the current order is probably just the beginning for the implementation of UWB technologies. The report frequently notes that these are cautious steps towards a broader implementation.

Vehicular radar is intended for collision avoidance, improved airbag functioning and improved suspension systems. An implementation may include 12 transmitters per vehicle mounted on bumpers and fenders at a height of 0.5 m. Millimeter wavelengths are preferred for operation because of the need for a small antenna and small beam and because of the need for significant attenuation at increasing distances.

The emitted signal is pulsed in short bursts. One can estimate the temporal occupancy of the radar as follows. If the radar is intended to give 1 foot accuracy over 100 m, then it must produce pulses with a temporal occupancy < 0.01 on timescales less than 1 msec. We will take the upper bound as a conservative estimate. The mean flux density will be reduced by this factor. On timescales longer than 1 msec, the temporal occupancy will be determined by specific implementation. There are no apparent regulations on temporal occupancy.

The constraints on emission levels are given in the FCC order (Table 1). The FCC gives limits on emission in terms of EIRP, the total power emitted in a 1 MHz band. We evaluate this emission in terms of the flux density at a distance of 1 km. These calculations are for a single device.

Directional antennas are required for the radar in order to attenuate the signal above the horizontal plane for the purpose of protection of passive sensing of the Earth from satellites. The signals must be attenuated by 25 dB at an angle of 38 degrees above the horizon.

Actual vehicular radar systems at 76 GHz have been measured and shown to produce a wide range of emitted powers (Clegg 1996). Measurements of the third harmonic power level for three devices were found to produce 0.0004, 0.04 and 1000 pw/cm^2 at 3m. All devices met the FCC standard. The latter device corresponds to a flux density of 10^5 Jy at 1 km in 100 GHz.

Damage to or the lack of maintenance for these devices may lead to performance outside of the FCC limits.

2. Effects of Vehicular Radar on CARMA

Propagation effects through the troposphere will produce attenuation on the order of < 1 dB/km. These are largely negligible considering the strength of the signal. Moreover, these effects are weakest when the observing conditions are the most favourable.

The probability of detection of the radar signal in the primary beam of an antenna is small. Detection is most likely to be made in a far out sidelobe which will have a gain of $\sim$ 35 dB less than in the primary. This suppression will lead to instantaneous and mean flux densities of 200 Jy and 2 Jy at 24 GHz, respectively. Above 31 GHz, instantaneous and mean flux densities will be 2 Jy and 20 mJy.

The overall effect on imaging will be determined by the temporal occupancy on timescales longer than 1 msec. This includes the number of vehicles that pass near to the site and the duration of their proximity, as well as unregulated details of the radar implementation. Mitigation may be as simple as editing a few bad points or as bad as rejecting an antenna.

The practical effect on imaging will be a loss in dynamic range and sensitivity. In the extreme case of strong signals entering the main beam, SIS mixers may saturate. Effectively, this will lead to an artificial horizon for each antenna. Water vapor radiometers functioning at K-band may be especially sensitive to this interference.

Terrain and distance from the radar are the most important mitigating factors. Limiting line of sight propagation will lead to a substantial reduction of the interference. Diffraction, scattering and other effects will enhance the propagation around obstacles. For example, research in Green Bank has demonstrated that scattering of 1.3 GHz aircraft radar off terrain, airplanes and rain clouds are all important effects (Fisher 2001). An accurate computation requires detailed modeling.

Fringe rotation will also limit the effects of vehicular radar. Rapid rotation of the phase of the interfering signal will lead to a decrease in the correlated interference at a rate faster than $t^{-1/2}$. The maximum rate of phase change for a system that implements delay compensation at a frequency ν_d is

$$\dot{\phi} = 2\pi\nu_d \frac{v}{c} \text{ rad s}^{-1}, \tag{1}$$

where v is the velocity of the radar and c is the speed of light. For $v = 100$ km h^{-1} and $\nu_d = 1$ GHz, we find that the phase will wrap on a timescale of 10 msec. A more typical result can be found assuming motion perpendicular to a 100 m baseline at a distance of 1 km. This will lead to a phase wrap on a timescale of 2 sec. In general, short baselines will suffer more than long baselines. Stationary sources will also suffer fringe rotation at the sidereal rate.

REFERENCES

FCC 02-48 http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-02-48A1.pdf

Clegg, A.W. 1996, “IEEE Vehicular Radar and Radio Astronomy,” IEEE VRS-96-6 http://www.its.bldrdoc.gov/~allen/IEEE_VRS/VRSDocs/VRS_96_6.pdf

Fisher, R. 2001, “Analysis of Radar Data from February 6, 2001,” http://www.gb.nrao.edu/%7erfisher/Radar/analysis.html

Table 1. Power limits for 24 GHz Vehicular Radar

Frequency (GHz)	EIRP (dBm/MHz)	Peak Flux Density at 1 km (Jy)	Mean Flux Density at 1 km (Jy)	Peak Flux Density at 1 km in sidelobe (Jy)	Mean Flux Density at 1 km in sidelobe (Jy)
0.960 - 1.610	-75.3	230	2.3	0.08	0.0008
1.610 - 22	-61.3	5900	59	2	0.02
22 - 29	-41.3	590000	5900	200	2
29 - 31	-51.3	59000	590	20	0.2
$>$ 31	-61.3	5900	59	2	0.02