Technical Report

SVR-500
Interference Immunity

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Summary

The performance of the SVR-500 radar is not degraded to any discernible extent by interference, either from vehicle-mounted radars or from other roadside-mounted equipment.

The vast majority of vehicle-mounted radars in intelligent cruise control systems use a totally different frequency band to the SVR-500 and as far as we are aware all new developments are in that band. However there are a few existing vehicle equipments that use the same operating frequency as the SVR-500. It has been shown in many years of operation that there is no significant degradation in performance even in worst-case situations because there is merely an intermittent loss of signal in a small and changing part of each scan.

Fixed roadside-mounted equipment presents a more serious challenge because it may be installed close to the SVR-500 and can transmit constantly. To assess the effects of this, tests have been conducted with a roadside-mounted radar when it is installed in the absolute worst case: co-located with and pointing in the same direction as the SVR-500. The results show that even with this arrangement, the effects of the interference are minimal.

Worst Case: HADECS3 Speed Camera

In the UK, the Highway Agency Digital Enforcement Camera System 3 (HADECS3) speed camera system is widely deployed. It uses the same 24 GHz operating frequency as the SVR-500 and transmits using both CW and FMCW radar modes at the maximum permissible amplitude for the 24 GHz ISM band: 100mW (+20dBm). HADECS3 represents a very credible worst-case interference source against which the SVR-500 can be characterised.

A particularly demanding installation is when the HADECS3 and the SVR-500 are positioned side-by-side. In this arrangement there are two transmission paths. One is directly from the HADESC3 to the SVR-500 where interference can be suppressed by simple shields to block the line-of-sight. The second path is from the HADECS3 after reflection from nearby vehicles to the SVR-500. Since the path lengths can be relatively short and the vehicles can present a large area, substantial amounts of the HADECS3's energy can be reflected back toward the SVR-500 with no practical shielding mechanism being possible. This is therefore the worst case.

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Figure 1 - Typical HADECS3 roadside installation – radar is positioned on the right.

Test Method

The test method specified by National Highways required SVR-500 to be positioned 15m away from HADECS3 with the radars pointing directly at each other. This gave a signal level equivalent to having the two equipments side-by-side with both of them looking at a perfect (infinite) reflector 7.5 metres away.

Since vehicles are not perfect reflectors the actual reflectivity had to be determined. This was achieved by using the SVR-500 to measure vehicles on a section of a UK motorway during a busy 20-minute period to produce a dataset of vehicle reflectivity against angle and range. A subsequent series of laboratory measurements were undertaken to calibrate these reflectivity measurements against practical implementations of perfect reflectors.

In this way the calibrated data measured on the motorway was used to scale the measured HADECS3 powers to determine the interference power seen at the SVR-500 if it were received after reflections from the vehicles on the motorway instead of directly from the HADECS3.

From this, the signals measured due to interference and actual vehicles could be compared. The most convenient way of doing this was to compare the threshold levels that the SVR-500 automatically generated to prevent false alarms. The thresholds are dynamic and adapt to changes in the environment, including traffic and congestion. If the thresholds due to interference were lower than those due to vehicles there would be no real reduction in detection probability.

Results

Figure 2 shows the received interference level from the static HADECS3 measured over 120 frequency scans. The energy is distributed across every range cell up to 250m. Black and red traces show the signal level, which increases with range. This slope is due to the gain characteristics of the SVR-500 receiver, which compensates for lower signal levels at longer ranges. A scaled version of this gain response is shown as the pink trace for reference.

When the gain response is taken into account, it shows the interference power is actually fairly constant in all the range cells. Further analysis suggests the relatively large signals below 20 metres are likely caused by reflections from nearby large objects via the antenna sidelobes.

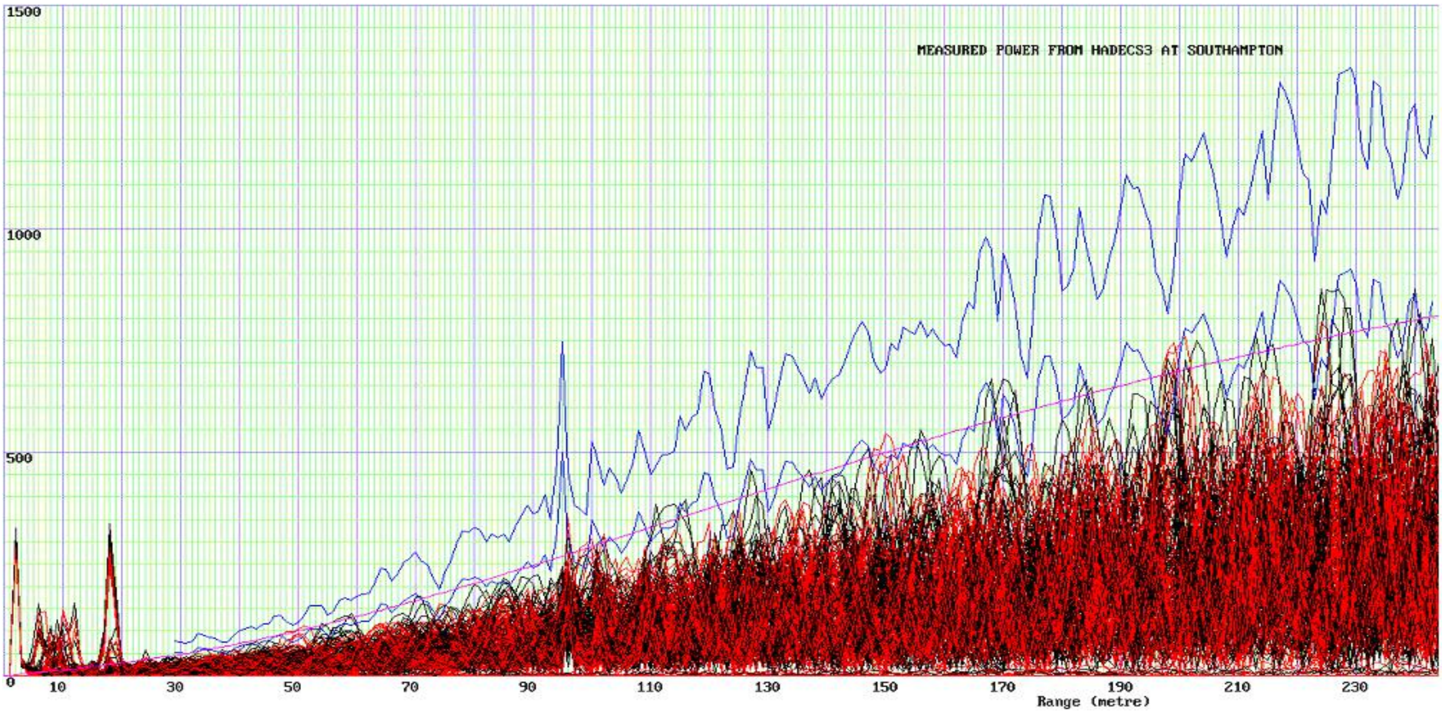

Figure 2 – Measured power received from HADECS3

The upper blue trace shows the approximate SVR-500 threshold level. Although the algorithm for producing the threshold is very sophisticated, a simplification is to set the threshold in any range and angle cell to 1.5 times the largest signal value observed in that cell in the previous 20 seconds. The lower blue trace is this simplified threshold divided by 1.5, which confirms the approximation is valid for our purposes as it is similar in amplitude to the peaks from the red and black traces.

Figures 3 and 4 show the computed threshold levels of the vehicles measured in two different directions, one looking up the motorway, the other down. The black plots were when vehicles were illuminated by SVR-500 and red plots were same vehicles illuminated by HADECS3 interference. It can be seen that the interference levels (red) are very low compared to normal operation (black), suggesting high immunity to interference.

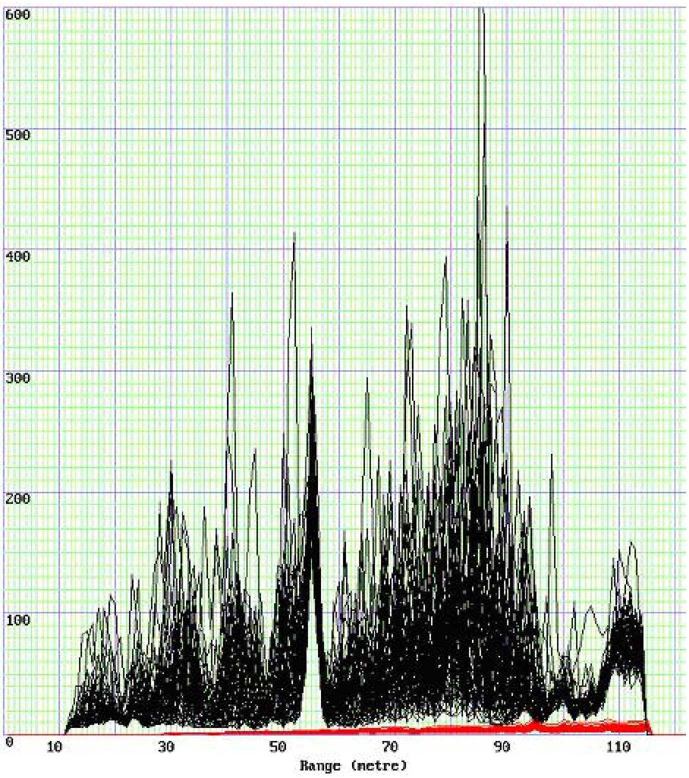

Figure 3

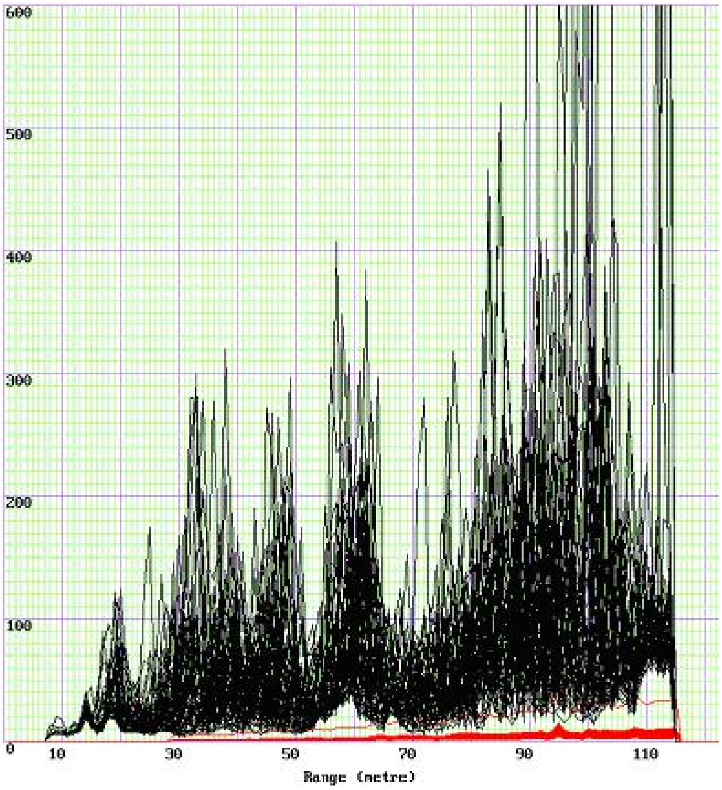

Figure 4

In all but one case the thresholds due to vehicles illuminated by SVR-500 were higher than the thresholds due to illumination by the HADECS3 interference source.

There was one instance shown on figure 4 where the threshold due to interference was roughly equal to the very lowest thresholds during normal operation. This was due to a large vehicle with unusually high reflectivity changing lanes on the far carriageway, during which time it was angled briefly to provide near specular reflections of the radar beam. Even so, it only just managed to increase the threshold due to interference to a level equal to the lowest points of the normal threshold, so the overall effect is insignificant.

If a similar event occurred on the near carriageway, then the magnitude of the radar returns would not alter substantially although the interference could be increased by as much as the ratio of the gains at 100 metres to that at 30 metres, which is 6:1. In this case the interference threshold value would increase up to amplitude 200 at 115 metres.

In these circumstances there would be a noticeable, though still not significant, reduction in the sensitivity at the longer ranges in that direction. However it would only exist briefly in the 10-degree sector in which both the main beams of the HADECS3 and SVR-500 could be present. On the basis of the results shown, this potential event would occur for less than 1% of the time and would only cause a relatively small degradation in approximately 5% of the SVR-500's total coverage area.

Conclusion

The overall conclusion is that the interference, even when arranged to give the worst-case degradation does not cause any serious problems. In the measurements taken over 20 minutes looking in both directions there was only one case in 120 where a noticeable but small reduction in sensitivity would be observed. This would be temporary, at longer ranges and in only 5% of the total coverage area, which suggests that in the worst case, the overall detection probability may reduce by 0.05% at most. Since the threshold adapts continually as new data is fed in, any slight reduction in sensitivity would improve quickly.

Since HADECS3 transmits at the maximum permitted power level in the same 24 GHz band as SVR-500, we have demonstrated a high immunity to realistic worst-case in-band interference, which is the hardest to mitigate. SVR-500 readily blocks out-of-band signals at other frequencies, which can safely be ignored.

A computer simulation of the SVR-500 operation was undertaken in the presence of the interference on a sample-by-sample basis including the filtering, shaping and signal processing. This showed that the interference measured at the receiver's down-converting mixer output was very broadband, many times that of the normal vehicle returns. However the high performance anti-aliasing filters used in the receiver rejected these out-of-band emissions and because of this, the digital signal processing sees only a very small proportion of the interference that will be reflected from vehicles.

HADECS3 represents a substantially greater interference problem than from 24 GHz automotive radars. Not only is the HADECS3 typically located much closer than distant vehicles, but also any interference from vehicles is short-lived as they move along the road. Even during traffic jams where the vehicles do not move, their low-mounted radars tend to have restricted line-of-sight due to obscuration from other nearby vehicles.

Relatively few vehicles are actually fitted with 24 GHz radars, as the frequency allocation is being phased-out for automotive use. Instead the vast majority use 77 GHz, so much so that in the USA there is a ban on fixed roadside radars with 77 GHz operating frequency to prevent interference problems. Since SVR-500 does not operate at 77 GHz there is no risk and the design is "future-proof".

The particular configuration of SVR-500 and HADECS3 that was tested represents the worst-case physical arrangement. While important to establish performance under worst-case conditions, in reality it will usually be possible to position SVR-500 further away or in an alternative position, further reducing the level of interference.

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