A REVIEW OF
AUTOMOTIVE RADAR SYSTEMS -
DEVICES AND REGULATORY FRAMEWORKS

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A REVIEW OF AUTOMOTIVE RADAR SYSTEMS – DEVICES AND REGULATORY FRAMEWORKS

1. Introduction

Automotive radar devices are now appearing on many transport and luxury passenger motor vehicles used in Europe and the United States of America (USA). These devices are employed in advanced cruise control systems, which can actuate a motor vehicle’s accelerator and/or brakes to control its distance separation behind another vehicle. Examples of such systems are BMW’s “Active Cruise Control”, Jaguar’s “Adaptive Cruise Control” and the Daimler-Benz “Distronic” system. It is anticipated that the use of these systems will become commonplace in the future.

A number of vehicle importers are seeking to bring cars with intelligent cruise control systems into Australia. The proposed systems employ pulsed radar devices operating within the frequency range 76 – 77 GHz.

Pulsed radar devices incorporate radiocommunications transmitters. It is generally a requirement of the Radiocommunications Act 1992 that the operation of all radiocommunications transmitters is licensed. It is therefore necessary to explore how the operation of these devices might be supported in Australia.

This report examines overseas and international regulatory frameworks and standards currently in place for this application, and compares bands used by other countries for automotive radar with Australia’s uses of these bands. It also examines the sharing possibilities within the 76 – 77 GHz band in Australia. To assist with this examination the report presents currently available technical information on automotive radar and a description of any relevant propagation characteristics of the 76 – 77 GHz band. The report concludes by recommending an appropriate radiocommunications licensing arrangement, including technical limits of operation, to support the use of these systems in Australia.

2. Automotive Radar Equipment

The following automotive manufacturers are known to be including automotive radar devices on vehicles: Daimler-Benz, BMW, Jaguar, Nissan, Toyota, Honda, Volvo and Ford. Fujitsu, an electronic component manufacturer, is known to be producing semiconductor devices specifically for automotive radar systems.

A typical automotive radar is mounted behind the front grille of a vehicle at a height of less than 1 metre, where it is able to interrogate the road ahead and the adjacent traffic lanes forward of the vehicle’s location. Using this radar an activated intelligent cruise control system within a vehicle adjusts the vehicle’s road speed in response to a slower vehicle in a merging lane, or when following a vehicle in the same lane, in order to maintain the driver’s selected minimum separation distance behind the other vehicle. The intelligent cruise control system would also sound an alarm and disengage itself if closing speed or separation distance to an object exceeded safe margins.
The following technical characteristics, drawn from detailed technical information (some of which is proprietary) supplied by the Australian automotive industry, summarise the key radiofrequency aspects of the automotive radar component of the intelligent cruise control systems that the industry is keen to make available in this country:

- **System type:** pulse
- **Frequency Band:** 76 – 77 GHz
- **Emission bandwidth:** up to 500 MHz
- **EIRP (max):** up to 20 Watts
- **Average EIRP:** < 10 mW
- **Antenna beamwidth (max):** 4° elevation, 15° azimuth

### 3. Overseas Regulatory and Standards Arrangements

#### 3.1. European Conference of Postal and Telecommunications Administrations

The European Conference of Postal and Telecommunications Administrations (CEPT) represents 43 European regulators. CEPT, through European Radiocommunications Committee (ERC) Decision (92)02 [1], decided that the 76 - 77 GHz band should be designated to vehicular radar systems on a non-exclusive basis. This decision is also supported by ERC Report 3, “Harmonisation of Frequency Bands to be Designated for Road Transport Information Systems” [2]. This report states that “Within CEPT countries very little use is made at present of this band, so the band 76 – 77 GHz could be made available for vehicle radars”.

#### 3.2. Federal Communications Commission Regulations

Part 15.253 of the Federal Communications Commission (FCC) regulations supports the use of the frequency bands 46.7 - 46.9 GHz and 76.0 - 77.0 GHz within the USA for vehicle-mounted field disturbance sensors used as vehicle radar systems. FCC Part 15.255 specifically excludes the use of “field disturbance sensors, including vehicle radar systems” in the band 59 – 64 GHz, unless employed for fixed operation.

#### 3.3. International Telecommunication Union

International Telecommunication Union (ITU) Recommendation ITU-R M.1310 [3] provides the radio requirements aspects of Transport Information and Control Systems (TICS). TICS include emergency management systems, electronic payment services, fleet management systems, public transportation systems (two way mobile – base) and advanced vehicle control systems. Automotive radar is identified as an element of an advanced vehicle control system.
Draft Recommendation ITU-R M.[TICS.RADAR] [4] recommends the bands 60 - 61 GHz and 76 - 77 GHz for use by automotive radar systems. This draft recommendation describes the technical and operational characteristics of low power, short-range radar used as part of a larger transport and control system. It refers to and takes into account the:

- FCC application of the 76 – 77 GHz band for this purpose,
- Ministry of Post and Telecommunication (MPT) of Japan’s application of the 60 - 61 GHz band and the 76 – 77 GHz band for this purpose,
- European Telecommunications Standards document EN 301 091 1998-06 which applies to automotive radar equipment in the 76 - 77 GHz bands, and
- Asia-Pacific Telecommunications Standardisation Program (ASTAP), which has approved a proposal on a draft standard on "Low Power Short-Range Vehicle Radar Equipment Operating in the 60 - 61 GHz, and 76 - 77 GHz bands".

### 3.4. European Telecommunications Standards Institute

European Telecommunications Standards Institute (ETSI) standard EN 301 091 (1998-06) [5] specifies the requirements for a short range 76 GHz to 77 GHz radar intended for Road Transport and Traffic Telematics (RTTT) applications (amongst others), such as Automotive Cruise Control (ACC), Collision Warning (CW) and Anti-Collision (AC) systems for vehicles.

### 3.5. Summary: Frequency Bands for Automotive Radar

Table 1 is a summary of the various frequency bands (by overseas organisation) in which the use of automotive radar is supported.

<table>
<thead>
<tr>
<th>Frequency Band(s) Supported</th>
<th>Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>76 - 77 GHz</td>
<td>CEPT (Europe)</td>
</tr>
<tr>
<td>76 - 77 GHz</td>
<td>ETSI (Europe)</td>
</tr>
<tr>
<td>46.7 - 46.9 GHz, 76 - 77 GHz</td>
<td>FCC (USA)</td>
</tr>
<tr>
<td>60 - 61 GHz, 76 - 77 GHz</td>
<td>ITU</td>
</tr>
<tr>
<td>60 - 61 GHz, 76 - 77 GHz</td>
<td>MPT (Japan)</td>
</tr>
</tbody>
</table>

**Table 1 - Frequency Bands supporting Automotive Radar**

### 4. Existing Spectrum Allocation Arrangements

Generally speaking, automotive radar devices appear to fall under the definition of the Radiolocation service in the Australian Radiofrequency Spectrum Plan (ARSP), although one aspect of their functioning (obstruction warning) may be more closely aligned with the Radionavigation service definition. In any case the broader definition of the Radiodetermination service, which subsumes the Radiolocation and Radionavigation services would certainly capture all aspects of their operation.
The ITU and Australian spectrum allocations covering bands mentioned above for automotive radar are as follows:

<table>
<thead>
<tr>
<th>Band (GHz)</th>
<th>International (Regions 1, 2 and 3)</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>43.5-47</td>
<td>MOBILE 533</td>
<td>MOBILE 533</td>
</tr>
<tr>
<td></td>
<td>MOBILE SATELLITE</td>
<td>MOBILE SATELLITE</td>
</tr>
<tr>
<td></td>
<td>RADIONAVIGATION</td>
<td>RADIONAVIGATION</td>
</tr>
<tr>
<td></td>
<td>RADIONAVIGATION-SATELLITE</td>
<td>RADIONAVIGATION-SATELLITE</td>
</tr>
<tr>
<td></td>
<td>554 AUS1</td>
<td>554</td>
</tr>
<tr>
<td>59.3-64</td>
<td>FIXED</td>
<td>FIXED</td>
</tr>
<tr>
<td></td>
<td>INTER-SATELLITE</td>
<td>INTER-SATELLITE</td>
</tr>
<tr>
<td></td>
<td>MOBILE 558</td>
<td>MOBILE 558</td>
</tr>
<tr>
<td></td>
<td>RADIOLOCATION 559</td>
<td>RADIOLOCATION 559</td>
</tr>
<tr>
<td></td>
<td>138 AUS62</td>
<td>138</td>
</tr>
<tr>
<td>76-81</td>
<td>RADIOLOCATION</td>
<td>RADIOLOCATION</td>
</tr>
<tr>
<td></td>
<td>Amateur</td>
<td>Amateur</td>
</tr>
<tr>
<td></td>
<td>Amateur-satellite</td>
<td>Amateur-satellite</td>
</tr>
<tr>
<td></td>
<td>Space research (space-to-earth)</td>
<td>Space research (space-to-Earth)</td>
</tr>
<tr>
<td></td>
<td>560 AUS62</td>
<td>560</td>
</tr>
</tbody>
</table>

Table 2 - Extract of Australian Radiofrequency Spectrum Plan Table of Allocations

Although the USA supports the use of automotive radar in the 46.7 – 46.9 MHz band, this band is not allocated to the Radiolocation service in any ITU Region; it may be that automotive radar is being supported under the Radionavigation service allocation instead. In Australia the main use is for Defence purposes (footnote AUS1).

The 60 – 61 MHz band for automotive radar lies within the 59.3 – 64 MHz band, which is allocated to the Radiolocation service on a primary basis across all three ITU Regions. The band 59.3 – 64 MHz is also allocated to the Fixed, Inter-satellite and Mobile services on a primary basis, and may be used by airborne radars in the Radiolocation service (international footnote 559). Part of this band (61 – 61.5 MHz) is designated for industrial, scientific and medical applications (international footnote 138). Defence interests in Australia are indicated by footnote AUS62.

The 76 – 77 GHz frequency segment for automotive radar lies within the 76 – 81 GHz band. Across all three ITU Regions this band is allocated to the Radiolocation service on a primary basis, and to the Amateur, Amateur-satellite and Space Research (space-to-Earth) services on a secondary basis. Defence interests in Australia are indicated by footnote AUS62.

From 1 January 2002, Radioastronomy becomes a shared primary allocation in the band 76 - 77.5 GHz.

At this time there are no ACA frequency band plans or Radiofrequency Assignment and Licensing Instructions (RALIs) that would provide more detailed allocation advice for these bands.

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1 Reference: Final Acts, ITU World Radiocommunication Conference 2000, Istanbul. The primary allocation to the Radioastronomy service will be reflected in the ARSP in the same timeframe.
International plans for integrated vehicular systems (ie ITU TICS, ETSI RTTT) all recommend the use of the 76 – 77 GHz band for automotive radar systems. Other bands are recommended for the various other components of integrated vehicular systems. At this time, no vehicle manufacturers or importers have sought domestic support for the use of systems in bands other than the 76 – 77 GHz band. For these reasons it is not considered necessary to explore supporting the use of automotive radar or any associated devices in bands other than 76 – 77 GHz at this time. Accordingly the remainder of this paper considers only this band.

5. Current Uses of the 76-77 GHz Band

At this time the ACA has not issued any apparatus licences for the operation of equipment within the 76 – 77 GHz band. There are also no class or spectrum licensing arrangements applicable to this band.

The Wireless Institute of Australia “Yearbook 2000” [7] does not provide detailed band planning recommendations for the use of the Amateur service allocation in the 75.5 - 81 GHz band (detailed plans exist up to around 24 GHz). There appears to be no amateur use of this band terrestrially in Australia at this time. There are no amateur satellites operating within this band.

6. Propagation Characteristics in the 76 - 77 GHz Band

Radiowave propagation in the EHF range (30 – 300 GHz) is generally line-of-sight; any obstruction in the optical path is indicative of considerable attenuation in the radiowave path. With the exception of reflection, line-of-sight conditions are generally required for successful propagation of an EHF signal.

Within various parts of the EHF spectrum, signals are attenuated by absorption by atmospheric gases. Absorption by oxygen and water vapour accounts for much of this attenuation. ITU Recommendation ITU-R P.676-4 [6] provides procedures for calculating gaseous attenuation for dry air and water vapour. According to ITU-R P.676-4, the combined attenuation for air and water vapour is 0.3 – 0.5 dB/km within the band 76 - 77 GHz. The range of a typical automotive radar system is 150 metres, or 300 metres round-trip; attenuation by air and water vapour will account for about 0.09 – 0.15 dB of signal attenuation. It is reasonable to ignore this loss and apply a free-space propagation model to this application, ie:

\[
\text{Path Loss} = 32.5 + 20 \log(f_{\text{MHz}}) + 20 \log(d_{\text{km}})
\]

Example: At 76.5 GHz, and for a distance of 100 metres, path loss is 110 dB.

Note: Much of the path loss is attributed to the very high frequency used - over a given distance a signal at 77 GHz will experience 60dB, or 1 million times, more attenuation that a signal at 77 MHz.

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2 AMSAT website: http://www.amsat.org
7. Discussion

7.1. Likely Growth in the Use of Automotive Radar Systems

Several luxury vehicle manufacturers offer intelligent cruise control systems already, and other manufacturers are on the threshold of releasing vehicles with these systems. As consumer demand and economies of scale occur, features offered on luxury vehicles tend to become available on most vehicles. It is anticipated that automotive radar systems will become relatively commonplace within a few years.

7.2. Frequency Band Requirements

From an examination of overseas regulatory and manufacturing developments, and the general product characteristics supplied by the Australian automotive community, it is clear that the 76 - 77 GHz band is being developed as the primary band for automotive radar applications.

Technical information indicates that the nominal operating frequency of an automotive radar system can vary by some hundreds of MHz due to manufacturing tolerances and component characteristics, and that the device’s frequency may also drift by a few hundreds of MHz during operation.

Noting the above, the whole of the frequency span from 76 GHz to 77 GHz should be considered as the band of operation of automotive radar devices.

7.3. Sharing/Interference Risks

Whilst there is no information available on protection requirements for other potential uses of the 76 – 77 GHz band, a number of characteristics of automotive radar systems and EHF propagation mitigate against automotive radar systems being a significant interference risk in the band:

- Although automotive radar systems may operate at peak (pulse) power levels up to 20 Watts EIRP, and this may seem to be a relatively high power, propagation loss in the 76 - 77 GHz band is much higher than that at lower frequencies (see free space loss equation in the previous section). For example, for a given distance an EIRP of 20 Watts at 77 GHz is equivalent to:
  - 20 mW EIRP at 2.4 GHz, or
  - 3 mW EIRP at 900 MHz;
  these are power levels readily associated with short-range applications and limited interference risk.

- Essentially, the emissions from automotive radar systems would be confined to flat narrow beams along highways and major urban roads.

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3 Cetecom Test Report 5-1598-3/99 measured a frequency drift of 174 MHz over a –25° to +55° temperature range.
• Radiowave propagation at the proposed frequencies is essentially line-of-sight, and the transmitting antennas are typically mounted at heights below one metre, so the radio horizon does not generally extend far.

• Above-horizon radiation is limited by the comparatively narrow antenna beamwidth in elevation (< 4°), augmented by operation in cluttered environments (e.g., built-up areas, tree lined roads).

Noting these factors, interference risk to other services that may be operated (in the future) under any of the allocations in the band 76 – 77 GHz is expected to be limited, or non-existent. Although the devices are short-range communications devices there may be, however, some localised site effects for radioastronomy or earth station receivers owing to their high sensitivity. Should a future assessment indicate some localised risk, it should be able to be handled through appropriate simple measures such as signage requesting car drivers to turn off intelligent cruise control devices, or speed limit restrictions that would force such devices to disable themselves. Radioastronomy sites already take equivalent measures with regard to ignition noise from motor vehicles.

Interference risk to automotive radar systems cannot be assessed at this stage; there are no other known uses. However, noting the clear international standardisation on this band for automotive radar systems, there would seem to be a strong case to sustain the viability of automotive radar systems through appropriate regulatory arrangements should other proposed uses of the band become apparent.

7.4. Licensing Considerations

Automotive radar systems are short-range narrow beamwidth radar devices activated, most probably unknowingly, by drivers when the intelligent cruise control fitted to the vehicle is engaged. They operate in the same band (76 – 77 GHz), sharing the spectrum by geographic separation from each other. Their technical and operational characteristics are such that they present little risk to each other, or other (potential) users of the spectrum. Any one device could be used anywhere across Australia, in an uncoordinated manner. Recognising their ubiquitous application, licensing arrangements for the use of automotive radar devices in the 76 – 77 GHz band need to be sufficiently flexible to be applied easily to the driver of the vehicle.

Conceptually, it does not seem sensible to be issuing drivers of motor vehicles with individual apparatus licences to enable them to operate lawfully the intelligent cruise controls in their vehicles. With regard to licence fees, an Australia-wide apparatus licence for the use of an automotive radar system exceeding 200 MHz bandwidth would attract an annual fee of around $60,000 per driver; for a bandwidth between 50 and 200 MHz the annual fee would be around $22,000. Such fees seem incongruous with the short-range, ubiquitous, spectrum sharing, low interference risk, uncoordinated operation of these devices.

Given the technical and operational aspects of these devices, authorisation under the ACA’s radiocommunications class licensing regime is the preferred licensing approach.

Class licensing support should be on a no interference/no protection basis, as this would seem to be the only viable regulatory basis on which to resolve interference disputes involving uncoordinated use, in the unlikely event that interference might occur.
approach also provides appropriate regulatory protection to frequency coordinated receivers, such as radioastronomy or earth station receivers, that may be licensed in the future in the same band.

The “Radiocommunications (Low Interference Potential Devices) Class Licence 2000” (the LIPDs class licence), which currently supports the licensed use of a wide range of short-range communications devices of benefit to the Australian community, would be the appropriate class licensing option.

Currently known automotive radar systems operate at maximum EIRP levels less than 20 Watts. An appropriate power limitation for the LIPDs class licence would therefore be a maximum EIRP of 25 Watts; this limit would support all known systems seeking support, and is likely to provide for future automotive radar systems. Given the propagation characteristics of the 77 GHz band, inclusion in the LIPDs class licence of a transmitter type with an EIRP limit of 25 Watts is not inconsistent with the intended purpose of this class licence.

Radiodetermination is the preferred class of transmitter as it avoids debate on the radiolocation/radionavigation issue – see Section 4 of this paper and the definitions of these three services in the ARSP. The application of this broader service allocation within the class licence is supported under S9 of the ARSP.

In summary, a new item in the Schedule to the LIPDs class licence as follows would support the use of automotive radar systems in Australia:

<table>
<thead>
<tr>
<th>Class of Transmitter: Radiodetermination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permitted Operating Frequency Band: 76 – 77 GHz</td>
</tr>
<tr>
<td>Maximum EIRP: 25 W</td>
</tr>
</tbody>
</table>

8. **Conclusions and Recommendations**

The 76 – 77 GHz band is recognised widely by overseas regulatory bodies, and by international and regional standards bodies, for automotive radar applications.

The interference risk presented by automotive radar applications to other potential users appears minimal, noting that the radioastronomy and space research communities may need to take some precautionary action locally at some future time.

The LIPDs class licence, with conditions as specified in the previous section, would be the appropriate licensing option to authorise use of these devices Australia wide.

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Bibliography


