Electronic conspicuity devices

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Executive summary

1. This report sets out the key outcomes of the Civil Aviation Authority (CAA) led project to develop a new industry standard for a low-cost electronic conspicuity (EC) device for use on light aircraft. It explores why such a standard is necessary, and looks at the key issues that need to be addressed to encourage more aircraft operators and owners to use EC devices. It then sets out a full technical specification that EC devices are required to meet, along with acceptable means of compliance.

Background

2. In uncontrolled airspace – that is, airspace where an air traffic control (ATC) service is not mandatory – pilots and other airspace users have long operated on a principle of 'see and avoid'. In other words, it is their responsibility to look out for other airspace users and avoid them.

3. Class G is a classification of airspace[1], commonly, although not exclusively, used in the UK by general aviation (GA) and military aircraft. There is a perception that the use of EC could reduce the risk of mid-air collision (MAC) in Class G airspace.

4. Electronic Conspicuity (EC) is an umbrella term for a range of technologies that can help airspace users to be more aware of other aircraft in the same airspace. It includes transponders and radios. At the most basic level, aircraft equipped with an EC device effectively signal their presence to other airspace users, turning the 'see and avoid' concept into 'see, BE SEEN, and avoid.' Many EC devices also receive the signals from others. This then alerts pilots to the presence of other aircraft which may assist the pilot in being able to visually acquire the aircraft and take avoiding action as necessary.

[1] Class G is the least restrictive of 8 airspace classifications described in ICAO Annex 11.

5. Although EC devices, such as Mode S transponders, are mandatory for specified aircraft, they are not universally mandatory in the UK for light aircraft that only operate in Class G airspace. Historically, transponders have been deemed prohibitively expensive for this kind of aircraft, and in some instances added too much additional weight and/or have unrealistic power requirements for the aircraft.

6. With respect to current, available surveillance technologies, it is anticipated that an EC device could offer similar functionality to FLARM, but use Automatic Dependent Surveillance-Broadcast (ADS-B) technology. It must be recognised at the outset that since EC devices are based on ADS-B transmitter/receiver technology, they are not a substitute for a transponder and cannot be used to fulfil the requirement where the carriage of a transponder is mandatory.

7. This report focuses on EC devices intended for voluntary carriage on registered and non-registered UK Annex II[2] aircraft; non-complex EASA aircraft of <5700kg MTOM and for gliders and balloons (including those covered under ELA 1 and ELA 2) within uncontrolled UK airspace. Since these are portable devices, the EASA requirements with respect to transmitting portable electronic devices (T-PEDs) on aircraft are recognised.[3]

[2] EASA has recently announced a new Basic Regulation under which it is proposed to rename "Annex II" to "Annex I".

[3] Consolidated Regulation (EU) 965/2012 Annex VII, NCO.GEN.125 and associated AMC/GM TO ANNEX VII (PART-NCO).

The establishment of an Electronic Conspicuity Working Group

8. Following safety recommendations made in a 2010 Air Accidents Investigation Branch (AAIB) report[4] into a collision in Class G airspace, an Electronic Conspicuity Working Group (ECWG) was established in 2014, under the auspices of the Airspace and Safety Initiative (ASI) Programme[5]. The ECWG consisted of representatives from:

- CAA
- Aircraft Owners and Pilots Association (AOPA)
- British Balloon and Airship Club (BBAC)
- British Gliding Association (BGA)
- British Hang Gliding and Paragliding Association (BHPA)
- British Microlight Aircraft Association (BMAA)
- Light Aircraft Association (LAA), and
- NATS.

4 See AAIB (2010) *Report on the accident between Grob G115E (Tutor), G-BYXR and Standard Cirrus Glider, G-CKHT at Drayton, Oxfordshire on 14 June 2009.* https://www.gov.uk/aaib-reports/5-2010-g-byxr-and-g-ckht-14-june-2009 (accessed 02.12.15).

5 The ASI was launched by the Civil Aviation Authority, Ministry of Defence and NATS in 2005. The aim of the initiative was to identify key areas for action to address the most pressing safety issues.

9. The ECWG was tasked to examine how increased use of EC in Class G airspace could improve safety through enhanced situational awareness. It was also tasked to develop an industry standard for an EC device against which developers could build new devices that would be suitable for use in GA.[6]

10. The ECWG concluded that it would be possible to develop an industry standard for an EC device that uses radio frequency (RF) and is based on ADS-B extended squitter (ES) technology. This provides more useful information to other airspace users than other solutions, while offering low cost and low power consumption. The ECWG members considered that it might be possible to produce such a device at a cost that, combined with the potential safety benefits, could encourage a significant proportion of the GA community to adopt it voluntarily. The ECWG therefore recommended that a project be initiated to take the development of such a standard forward.

11. In autumn 2014, the CAA commenced work on this project, supported by funding provided by the Department for Transport. A number of external organisations were involved, most notably:

- NATS
- the Light Aircraft Association (LAA)
- the Aircraft Owners and Pilots Association (AOPA), and
- QinetiQ.

The purpose and structure of this report

12. This report, jointly authored and reviewed by representatives of the above organisations, sets out the key outcomes of the CAA-led project to produce a new industry standard for a low-cost electronic conspicuity (EC) device for use on light aircraft. The project sought to create conditions which will encourage the manufacture of such EC devices, with the

6 See CAA (2014) ASI ECWG *Recommendations Paper: Electronic Conspicuity in Class G Airspace* CAP 1392. www.caa.co.uk/cap1329 (accessed 22.03.16).

ultimate aim of increasing voluntary equipage by the GA community. These are aimed at potential manufacturers of EC devices as well as the wider GA community.

- Chapter 1 provides the problem statement – the physiological and environmental limits of visual scan. It examines how supplementing ‘see and avoid’ could improve safety outcomes.
- Chapter 2 sets out recommendations on the minimum capability required of an EC device. It compares the EC devices being considered in this report with other airborne surveillance technologies, to show where this EC technology is ‘positioned’ in the market. Finally, it lists a range of features and design elements that the ECWG identified would encourage voluntary equipage by the GA community.
- Chapter 3 outlines the licensing requirements for owners/operators in relation to the use of EC devices.
- Chapter 4 summarises the obligations and responsibilities of manufacturers and aircraft owners with respect to the use of ICAO 24 bit addresses.
- Chapter 5 considers the spectrum management issues that could result from the increased use of EC devices. It explains how assurance has been provided to the National IFF/SSR Committee (NISC) that the specification for an EC device based on ADS-B technology would not lead to the manufacture of a device which could compromise the performance of air-to-air or air–to-ground safety nets.
- Chapter 6 sets out the Technical Specification Requirements, including interoperability considerations, for all EC devices. New devices, as well as existing devices, will be required to meet the Technical Specification. It also includes detailed Acceptable Means of Compliance (AMC) and associated guidance.

13. In addition to commissioning the EC project, the ECWG recommended[7] that the separate Visual and Electronic Conspicuity Working Groups should merge to form a single Conspicuity Working Group (CWG). This was implemented in July 2015 and the CWG now sits as a sub working group within the CAA's wider Mid Air Collision (MAC) Programme. The CWG has reviewed and provided input to this report.

14. It is recognised that further work will be required in the field of EC. However, by developing an industry standard for an EC device, this document represents an important milestone for EC.

[7] See CAA (2014) ASI ECWG *Recommendations Paper: Electronic Conspicuity in Class G Airspace* CAP 1392 para 1.5. www.caa.co.uk/cap1392 (accessed 22.03.16).

Chapter 1

Problem statement

The problem statement

1.1 Aircraft operating under Visual Flight Rules (VFR) in Class G (uncontrolled) airspace are not required to carry or use a radio, transponder or, other EC system, or communicate with Air Traffic Control. Instead, pilots and other airspace users rely on visual scanning to detect and avoid other traffic: this is known as the “see and avoid” principle. Visual scanning can however be affected by a variety of issues including: environmental conditions, aircraft design, pilot training and the limitations of the human eye.

1.2 By increasing the quality and quantity of information available to pilots, and thus increasing their situational awareness, EC devices could help reduce the risk of mid-air collision in Class G airspace.

What UK Airprox data shows

1.3 UK Airprox data indicates that late sighting or no sighting is a significant factor in risk bearing airproxes. The first issue is to establish whether there is evidence that failures of visual scan contribute to a substantial share of accidents, near-misses and other reportable incidents. In its 2012 report Class G Airspace For the 21st Century[8], the CAA recommended that an in-depth analysis be undertaken of the UK Airprox database to gain a deeper understanding of the risks of mid-air collisions within Class G airspace. This analysis could then be used to inform safety recommendations. The primary aim of the study was to investigate and

8 CAA (2012) – Class G Airspace for the 21st Century. Accessible from https://www.caa.co.uk/Data-and-analysis/Airspace-and-environment/Airspace/Future-airspace-strategy-documents/ (accessed 02.12.15).

document the specific causal and mitigating risk factors that increase the likelihood of a MAC within Class G airspace.

1.4 Sighting issues, i.e. a failure to see traffic or a late sighting of traffic, remain the most common causes of Airprox involving GA aircraft. However, such descriptions do not provide a full picture as to what factors led to a failure to see traffic. To secure better information in the future, an area of focus may be to extract that greater level of detail from the Airprox database and other safety data sources.

Enhancement of the visual scan

1.5 In addition to the known limitations of the human visual system, pilots operating in different aircraft, environments and tasks will have different styles and timings of a visual scan, some of which could be enhanced by EC.

1.6 Good practice recommends that pilots flying under VFR should spend most of their time looking out and scanning the airspace. However, there

are indications that pilots spend insufficient time on visual scanning and may not optimise their scans. EC could enhance their situational awareness through augmenting their lookout.

The value of additional cues

1.7 'See and avoid' can be more robust when additional cues are available, such as those provided via an Air Traffic Service (ATS), radio or EC. As an example, an Australian Transport Safety Bureau report[9] concluded that pilots are significantly more effective at seeing and avoiding other aircraft when they receive some form of additional cue – known as 'alerted search'.

1.8 It is important to acknowledge that there are concerns that reliance on 'cued' lookout could reduce the effectiveness of visual acquisition.

- There may be a danger of focusing the pilot's attention in one area and therefore potentially either acquiring the wrong target, or missing objects that are just outside this or in different parts of the sky.
- Pilots may become over-reliant on information provided on other aircraft, or fixated on the display, at the expense of maintaining an effective visual scan.
- Pilots may falsely assume that **all** aircraft are electronically conspicuous.

1.9 It must therefore be stressed that any EC device does not replace the need for effective visual scanning.

1.10 The emergence of technologies such as FLARM and ADS-B is seen as a positive step[10] to increase pilot awareness of surrounding traffic. There are an increasing number of devices being developed. However, at present it is not known whether these will be interoperable. Active

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9 Australian Transport Safety Bureau (1991) – *Limitations of the see-and-avoid principle*, Research Report ISBN 0 642 16089 9. https://www.atsb.gov.au/publications/1991/limit_see_avoid.aspx (accessed 14.12.15).

10 FLARM is in daily use in GA, and due to its effectiveness is being voluntarily purchased and fitted in significant numbers by GA pilots and aircraft owners.

coordination of development is needed to achieve maximum interoperability which in turn will mean increased efficacy of each device.

1.11 The considered opinion of the ECWG was that 1090MHz ES is a suitably mature technology and so provides the best opportunity to develop a specification for ECs in the short term. While the development of this technological specification concerns 1090MHz ES, it does not preclude the development of other technologies.[11]

11 As an example, the ECWG also saw merit in exploring Camera Based (CB) technology further.

Chapter 2

Minimum suggested capability

2.1 This chapter sets out recommendations for the minimum capability required of an EC device. It defines a Basic, Intermediate and Full EC device. It compares the EC devices being considered in this report with other airborne surveillance technologies, to show where this EC technology is ‘positioned’ in the market. Finally, it lists a range of features and design elements that the ECWG identified would encourage voluntary equipage by the GA community.

Categories of capability

2.2 In its recommendation paper[12], the ECWG defined three categories of EC device capability: Basic, Intermediate and Full. To place the EC device in the context of current available surveillance technologies described below and define the technology to be used, these have been elaborated on for the purpose of this report. The definitions are:

- ***Basic*** *– a transmit-only device with no alerts to the carrier*: using a commercial off-the-shelf (COTS), non-qualified GPS/GNSS[13] receiver and ADS-B transmitter conforming to the specification set out in Chapter 6 of this publication. No visual or audible alerts would be available to the user.
- ***Intermediate*** *– a transmit/receive device with minimal interoperability and audible only alerts*: an ADS-B transmitter/receiver using a COTS, non-qualified GPS/GNSS receiver offering interoperability with air and ground safety nets as

12 See CAA (2014) ASI ECWG *Recommendations Paper: Electronic Conspicuity in Class G Airspace* CAP 1392. www.caa.co.uk/cap1392 (accessed 22.03.16).

13 This refers to generic Global Navigation Satellite Systems (GNSS) and the United States NAVSTAR Global Positioning System (GPS).

detailed in Chapter 6 of this publication and providing audible and, possibly, visual alerts.

- ***Full** – a transmit/receive device interoperable with other air and ground safety nets with visual and audible alerts*: such a device is currently limited to secondary surveillance radar (SSR) technology and is considered outside of the scope of Chapter 6 of this publication.

2.3 The ECWG made it clear that it viewed ADS-B extended squitter technology as the most practical solution, due to the possibility of lower transmit power levels leading to lower power consumption, lower costs and the potential for interoperability with other ground and air users.

Comparison with other airborne surveillance technologies

2.4 Fundamentally, current airborne surveillance technologies consist of equipment installed on aircraft that provides:

- air-to-air safety nets, such as collision avoidance systems, and
- air-to-ground transmissions to assist in identifying the aircraft to air traffic control.

This equipment offers interoperability at varying levels across functional capabilities and ranges from Airborne Collision Avoidance System (ACAS) II and Mode S transponders, required for most commercial air transport aircraft operated in controlled airspace, to ACAS I, Traffic Advisory Systems (TAS) and Mode S transponders for aircraft that are not required to be equipped to the same level, but that are voluntarily equipped to improve surveillance capability and situational awareness. Although certification requirements still cover Mode A and C transponders, developments in airspace requirements have meant that these have been largely replaced by Mode S.

2.5 In harmony with a requirement from the Federal Aviation Authority (the US aviation regulator), from 2020, 1090MHz ES ADS-B out will be mandated for Europe for most commercial aircraft[14]. Specific requirements will apply to this. ADS-B out can also be voluntarily adopted for GA, provided these systems are able to report the position source accuracy and integrity metrics and overall system integrity metrics in a manner appropriate to the installation certification.

2.6 Traffic Awareness Beacon System (TABS) is a system which has been developed under an FAA Technical Standard Order (TSO)[15]. Its aim is to make GA aircraft visible to TAS, Traffic Alert and Collision Avoidance System (TCAS) I, TCAS II and ADS-B in equipped aircraft, and employs transponder and ADS-B technology.

2.7 FLARM was developed for GA use and provides an air-to-air safety net, but operates on a radio frequency spectrum outside of the aeronautical band. EC devices, in common with FLARM, offer conspicuity or situational awareness enhancement for users that cannot, are not required to or do not wish to carry transponder or collision avoidance systems, but wish to have some form of awareness enhancement because they recognise the safety benefit.

2.8 An intermediate EC device, for example, may offer similar functionality to FLARM, but operate using the 1090MHz airborne spectrum.

2.9 Since the requirement specification in this CAP covers the use of ADS-B based on downlink format (DF) 18, EC devices as specified here will not be interoperable with current interrogative airborne safety nets, such as ACAS (including hybrid surveillance), TAS or TABS, but offer the scope to provide visibility of GA aircraft to air navigation service providers (ANSPs). Use of COTS GNSS receiver chipsets and, where applicable, altitude transducers, will be acceptable on the basis that the accuracy and

14 COMMISSION IMPLEMENTING REGULATION (EU) No 1207/2011 of 22 November 2011 - laying down requirements for the performance and the interoperability of surveillance for the Single European Sky. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32011R1207 (accessed 06.12.16)

15 A TSO is a minimum performance standard for specified materials, parts and appliances used on civil aircraft. Receiving a TSO authorisation is both a design and production approval. It is not an approval to install and use the article in the aircraft.

integrity metrics reported by the device will be suitably limited. EC devices may report barometric or GNSS altitude.

2.10 A summary comparison of current surveillance systems, as well as where EC devices sit within them, can be found in Appendix A.

2.11 It is not envisaged that an EC device will be carried or operated on an aircraft that already has an air traffic control radar beacon system (ATCRBS) or Mode S transponder installed and operating. Where this is the case, the transmitter section of the EC device must be deactivated to avoid possible interference due to non-synchronised transmissions and duplication of information transmitted by the transponder and EC device.

Motivators to encourage voluntary uptake

2.12 As stated earlier, it is not mandatory for GA aircraft in Class G airspace to have an EC device and there is no appetite, either within the ECWG or among stakeholders, to change that. Instead, the goal is to create an environment which encourages more pilots to voluntarily equip their aircraft with an EC device.

2.13 To better understand what would encourage GA pilots to voluntarily adopt an EC device, the ECWG analysed stakeholder requirements. It concluded that to encourage voluntary equipage, devices must:

- provide a definable and quantifiable benefit for the user
- be cost-effective, and
- not hinder or restrict current ways of operating.

In addition any potential negative effects of an EC device in the aircraft must be clearly understood.

2.14 The ECWG identified a set of universal or common requirements; these form a design brief that is applicable to all stakeholders and for the basic capability. Meeting these would increase the likelihood of voluntary uptake. The ECWG also identified additional elements that are stakeholder-specific.

Design brief

2.15 To encourage voluntary uptake from the widest cross-section of GA stakeholders, the design brief resulting from the ECWG's work is:

- **Portable**: there should be no barrier, either physical or regulatory, to moving the EC device from one aircraft to another instantly.
- **Light weight**: stakeholders identified a weight of approximately 200g including batteries could be acceptable.
- **Low bulk**: a device would ideally be no larger than approximately 140mm x 80mm x 25mm including batteries.
- **User friendly**: any EC device would be easy to operate, with minimal or no inputs required during flight. The device should not reduce 'look out' capabilities or have a negative impact upon safety.
- **Appropriate antenna fit**: the required antenna fit must be easily achievable and appropriate to the device.
- **Voluntary equipage**: the ECWG supports voluntary equipage of an EC device. There is no appetite for mandating carriage.
- **Minimal regulatory requirements**: stakeholders identified a requirement to have as few regulatory hurdles as possible. This will provide further positive encouragement for voluntary carriage.
- **Interoperable**: any system should be interoperable with as many players as possible.

2.16 The additional elements identified by the ECWG[16] to encourage voluntary uptake from the widest cross-section of GA stakeholders were:

- **Audible alerts**: audible alerts were identified as essential by most user groups. An audible alert must be unique from other inputs

16 See CAA (2014) ASI ECWG *Recommendations Paper: Electronic Conspicuity in Class G Airspace* CAP 1392 para 1.12.ii. www.caa.co.uk/cap1392 (accessed 22.03.16).

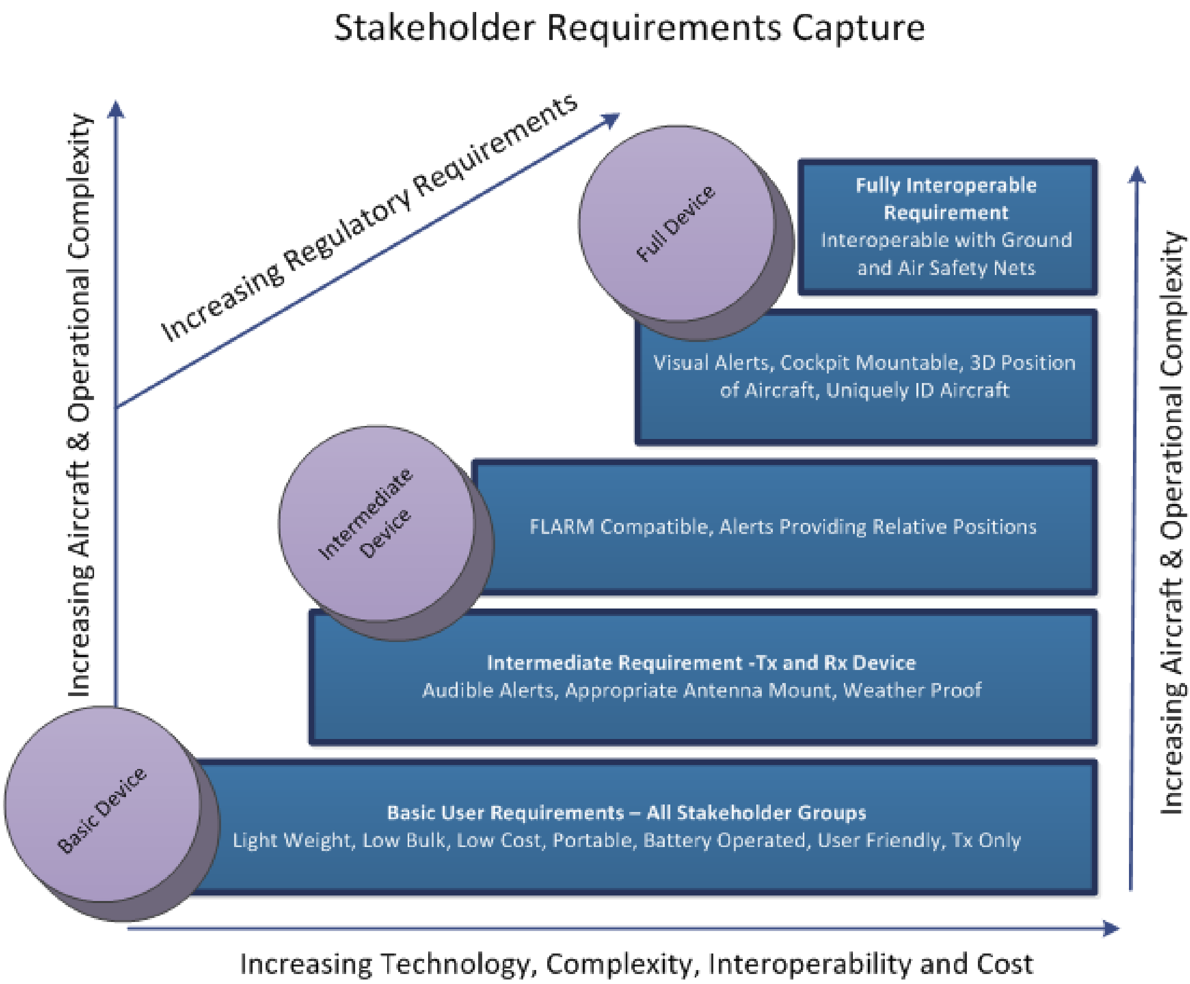
received by the pilot. All alerts must be timely and useful and any alert must not unduly distract the pilot from the ability to operate the aircraft or maintain good look-out practices.

- **Visual alerts**: when desired, must be user friendly on an appropriately sized and fitted display.
- **Low cost to the stakeholder**: stakeholders assessed that an acceptable cost for the most basic EC device would be approximately £250.00 including VAT. Minimal to nil through-life costs would also be desirable. Stakeholders recognise that additional functionality will result in additional cost to the stakeholder.
- **Cockpit mountable or user carried**: the EC device must be safe to carry on a person or be easily mountable onto the aircraft or in the cockpit.
- **Self-contained EC device**: some stakeholders will require an EC device that is completely separate from all other aircraft systems. However, some stakeholders may require interoperability with other devices in the cockpit. It is recognised that a device that is not self-contained may attract additional regulatory burdens.
- **Power options**: stakeholders who operate aircraft with internal power require an option to connect to the internal power source. Stakeholders without internal power assessed that a battery life of 12 hours would be acceptable and would ideally include the ability to rapidly charge the EC device.
- **Capable of operating within close proximity of handheld radios** without detriment to either system.
- **Full weather proofing and low temperature capable** to at least the same standard as the GPS systems used by walkers, as in some aircraft the equipment will be fully exposed to the elements.
- **Operable when wearing ski gloves**: in some aircraft the pilot and equipment will be fully exposed to the elements.

2.17 The CWG endorsed these recommendations but specifically concluded that the immediate need was for a technical standard that sets out fundamental safety and operating requirements for an EC device. This need is fulfilled by the technical standard in Chapter 6 of this publication.

2.18 Figure 1 below shows how the technical requirements of an EC device increase in line with the increasing complexity of an aircraft type. The more complex the aircraft, the more important the additional features identified by the ECWG are likely to be.

Figure 1: Visual summary of capability and design brief



Chapter 3

Aircraft owner/operator responsibilities and licensing obligations

3.1 This chapter summarises the licensing obligations and responsibilities of aircraft owners and operators if they wish to use a 1090MHz EC device on their aircraft.

3.2 It is the responsibility of the owner/operator to understand the implications of using specific EC devices. To be legally used in an aircraft, EC devices that operate on 1090MHz aeronautical frequency band require a Declaration of Capability and Conformance[17]. **It is the owner's responsibility to check whether there is a relevant Declaration for their device.**

3.3 A list of manufacturers that have provided declarations can be found on the CAA website at www.caa.co.uk/General-aviation/Aircraft-ownership-and-maintenance/Electronic-Conspicuity-devices/ along with information about any associated issues. This list will be actively maintained by the CAA.

3.4 To operate **any** radio equipment, aircraft owners/operators must hold a valid Wireless Telegraphy Act (WTA) Aeronautical Radio Licence.1090MHz EC devices are radio-transmitting equipment, so are subject to this regulation.

3.5 Approved transmitting EC devices will be included under the licensee's WTA licence as standard once notified.

3.6 The WTA licence traditionally requires anyone using any radio equipment on the aircraft to possess (or be under the direct supervision of someone

[17] See Chapter 6, paragraph 6.22.

who possesses) a valid Flight Radio Telephony Operator's Licence (FRTOL) if one is legally required for its operation. This was because when this radio licence condition was introduced, it was assumed that all aircraft radio stations would include a voice telephony function.

3.7 Following discussions between the CAA and Ofcom, it has been agreed that, while a WTA licence is still needed, the pilot need not hold a FRTOL if the transponder is the only radio equipment on the aircraft. However, the WTA licence must be varied formally to remove the need for the FRTOL. Variations are available free of charge and on request. They must be kept with the WTA licence.

3.8 On purchasing an EC device, it is the responsibility of the aircraft owner/operator to complete the relevant application form to obtain a WTA Aircraft Radio Licence from the CAA[18]. An application can be made using application form DAP 1902 and completed online at www.caa.co.uk/DAP1902. As the EC device is intended to be portable, the applicant should annotate the Transportable Radio boxes in Section 5 of the form and does not have to specify an individual aircraft.

3.9 For further information on radio licensing, contact the Radio Licensing Section of the Safety and Airspace Regulation Group at the address below:

Radio Licensing Section, SARG
K6 Gate 6
CAA House
45-59 Kingsway
London WC2B 6TE

Tel. 0207 453 6555
Fax. 0207 453 6556

[18] The Radio licensing section of the CAA has been appointed by the Office of Communications (Ofcom) as its agent to distribute Wireless Telegraphy Act Aeronautical Radio Licences.

Email: radio.licensing@caa.co.uk

Chapter 4

Allocation of ICAO 24 bit address

4.1 All Mode S transponders are given a unique 24 bit address by the International Civil Aviation Organization (ICAO). This then becomes part of the Certificate of Registration for the aircraft on which the transponder is fitted. An aircraft which has an ICAO 24 bit address is known as a registered aircraft.

4.2 Because EC devices are designed to be portable, and potentially move from aircraft to another, different rules will need to apply to them.

4.3 This chapter summarises the licensing obligations and responsibilities of both manufacturers and aircraft owners. It is split into sections for convenience but both may wish to take note of all the guidance provided.

Manufacturer responsibilities

4.4 The EC device should not be pre-loaded with an ICAO 24 bit address.

4.5 The device should allow for the ICAO 24 bit address to be programmable/reprogrammable by the user. Manufacturers should put in place a means of mitigating incorrect 24 bit entry, such as a requirement to enter the 24 bit address twice. A function should also exist to clear the programmed 24 bit ICAO address, and to alert the user should no ICAO 24 bit address be entered. Full instructions on how to complete these tasks should be contained within the device operating manual.

4.6 Attention of manufacturers is also drawn to more detailed instructions and guidance contained in Chapter 6 and Annex A.

Aircraft owners' responsibilities

4.7 Different responsibilities will apply, depending on whether the EC device is carried on a registered or unregistered aircraft. Provisions exist for the device to be used on both: however, the instructions below should be followed.

4.8 If an EC device is bought to use on an unregistered aircraft, the owner is required to contact the CAA Infrastructure Section (email: NISC@caa.co.uk) shortly after buying the device. The owner must confirm their contact details and the make, model and serial number of the EC device. The CAA will then allocate the EC device a unique ICAO 24 bit address. The address can then be used on multiple unregistered aircraft without re-programming.

4.9 If the EC device is to be used on a registered aircraft, the existing ICAO 24 bit address for the registered aircraft should always be used. It is not necessary to apply for a separate ICAO 24 bit address from the CAA. On transferring the device between registered aircraft, the EC device ICAO 24 bit address should be reset and the new aircraft's address entered into the device.

4.10 If the device is re-sold, the vendor should clear any registered aircraft 24 bit code from the device before sale. The new purchaser should contact the CAA at the above email address to allow records to be updated and a unique code allocated if necessary.

Chapter 5

Avoiding spectrum interference

5.1 European Commission regulations state that "*spectrum used by surveillance systems should be protected to prevent harmful interferences*".[19] This means that any new radio or broadcast technologies must operate in a way that does not interfere with existing systems such as Identification Friend or Foe (IFF) and Secondary Surveillance Radar (SSR).

5.2 The ADS-B technology identified by the ECWG as the most suitable for EC devices operates at 1090MHz. In the UK, the Cabinet Office has delegated authority for frequency assignments in the Band 960-1215MHz jointly to the CAA and Ministry of Defence (MoD). Executive authority for such matters is exercised through the National IFF/SSR Committee (NISC).[20]

5.3 Unlike IFF/SSR interrogators, EC devices capable of 1090MHz extended squitter do **not** require specific NISC approval to operate, providing they comply with the requirements of Annex 10 to the Convention on International Civil Aviation Volume IV, or Standardisation Agreement (STANAG) 4193, as appropriate.

5.4 The NISC has published advice[21] that it does not intend to impose operational restrictions on such devices. However, if the cumulative effect of these types of equipment is found to have a detrimental effect on the RF environment, it may be necessary to impose approval procedures or restrictions on use.

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19 EU (2011) *Commission Implementing Regulation EU 1207/2011 laying down requirements for the performance and the interoperability of surveillance for the single European sky*. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011R1207 (accessed 02.12.15).

20 CAA (2008) *Operation of IFF/SSR Interrogators in the UK: Planning Principles and Procedures* CAP761. www.caa.co.uk/cap761 (accessed 02.12.15).

21 See reference 20 above.

5.5 It is therefore necessary to provide the NISC with adequate assurance that the technical specification for EC devices would not cause:

a. interference that compromises the performance of air-to-air safety nets such as TCAS or,
b. interference that compromises the performance of the ground surveillance infrastructure.

5.6 Item (b) has been addressed through a 2014 study by QinetiQ[22] which considered impacts on ground surveillance infrastructure.

5.7 However, there was still a requirement to provide assurance to the NISC that the specification for an EC device for GA would not compromise the performance of air-to-air safety nets.

5.8 To address this, the ECWG commissioned QinetiQ in 2015 to produce a research paper titled 'Impact of General Aviation Electronic Conspicuity on TCAS' into the risks of interference and how these could be avoided.

5.9 The full paper is included in Appendix D. A short summary is provided below.

QinetiQ's research into spectrum interference with TCAS

5.10 QinetiQ's study concluded that: "*EC devices such as those envisaged… will when operating at rates specified by international standards, have no effect on the operation of TCAS. They will be effectively invisible to TCAS. However, all Mode S signals that are received by the TCAS Interrogator within the window of an expected reply will need to be decoded to some extent before they can be rejected.*" Therefore "*EC devices will degrade TCAS's ability by interfering with the reception of wanted signals. If EC signals in the environment remain low in comparison to other sources of*

22 QinetiQ (2014) *Low Power ADS-B Transceiver (LPAT) RF Environment Modelling Study - Phase 2*, QINETIQ/14/01558.

FRUIT [False Replies Unsynchronised In Time], *the interference will be minimal.*"

5.11 The study also determined the effects of a worst-case single point of failure for an EC device on TCAS. It concluded that "*the worst credible single fault that an EC device could have* [on TCAS] *would be for the rate of ES to be well above that specified. This would not cause the TCAS system to change its behaviour, but would mean that it is more likely that a wanted signal would be garbled or lost.*"

Stakeholder feedback and follow on activity

5.12 The results of the study were briefed to the NISC on 16 November 2015. The NISC was content with the evidence presented and had no immediate safety concerns over the project.

5.13 Members of the CWG separately raised some questions about some of the data and models used in the study. In particular, some GA stakeholders commented that the numbers of GA aircraft which could feasibly use a transponder could realistically exceed the numbers used in the study models. In addition, at peak times such as at gliding competitions, the number of EC-equipped aircraft in a small geographical area could greatly exceed the assumptions modelled in terms of traffic density. These 'spikes' of activity could lead to an increase in the effects on TCAS. These concerns were noted by the NISC, but it reiterated that it considered the situation acceptable.

Chapter 6

Technical specification requirements

6.1 This chapter provides manufacturers with a comprehensive technical specification for portable, low-power EC devices utilising ADS-B extended squitter transmitters or transceivers employing DF=18 (Downlink Format 18) squitter. Only devices that meet this specification will be approved for use in the UK.

6.2 EC devices are intended for voluntary carriage on registered and non-registered UK Annex II[23] aircraft, non-complex EASA aircraft of <5700kg MTOM and for gliders and balloons (including those covered under ELA 1 and ELA 2) within uncontrolled UK airspace. **EC devices are not a substitute for a transponder and must not be considered as appropriate or suitable to fulfil any requirement where the carriage of a transponder is mandated**.

6.3 The specification is not applicable to EC devices used in any other category of aircraft.

6.4 The CAA recognises the EASA requirements with respect to transmitting portable electronic devices (T-PEDs) on aircraft as detailed in consolidated Regulation (EU) 965/2012 Annex VII, NCO.GEN.125 and its associated AMC/GM TO ANNEX VII (PART-NCO). In this context, the pilot-in command shall not allow carriage of such devices that could adversely affect the performance of the aircraft's systems and equipment. Since it is anticipated that aircraft eligible to carry EC devices will have minimal equipment and not have advanced systems, a requirement of EC device carriage is that appropriate checks must be made to ensure that no interference to existing aircraft systems and equipment results from the

[23] EASA has recently announced a new Basic Regulation under which it is proposed to rename "Annex II" to "Annex I".

carriage of an EC device. This information must be included in the EC device operating manual.

Relevant existing regulations and specifications

6.5 The technical requirements set out are based on a number of overarching regulations and specifications that many manufacturers will already be familiar with. These include:

- *Air Navigation: The Air Navigation Order 2016 and Regulations* CAP 393 Fifth edition Amendment 10[24], as amended and updated from time to time (Statutory Instrument 2016 No. 765 Civil Aviation The Air Navigation Order 2016 is reproduced in full).
- *British Civil Airworthiness Requirements (BCAR)* Section R – Radio Issue 4 April 1974[25]
- *Commission Implementing Regulation (EU) No 1207/2011 of 22 November 2011, laying down requirements for the performance and the interoperability of surveillance for the single European sky*[26]
- EASA *Certification Specifications CS-23 Amendment 5 Normal, Utility, Aerobatic and Commuter Aeroplanes*[27] and *CS-27 Amendment 3 Small Rotorcraft*[28]
- ICAO *Annex 10 Volume IV Fifth Edition July 2014: Surveillance Radar and Collision Avoidance Systems*[29]

24 CAA (2016) *Air Navigation: The Order and the Regulations* (fifth edition) CAP 393. www.caa.co.uk/cap393 (accessed 06.06.17).

25 CAA (1974) *British Civil Airworthiness Requirements Section R – Radio* CAP472. www.caa.co.uk/cap472 (accessed 03.12.15).

26 EU (2011) *Commission Implementing Regulation EU 1207/2011 laying down requirements for the performance and the interoperability of surveillance for the single European sky.* http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011R1207 (accessed 02.12.15).

27 EASA (2015) CS-23 Normal, Utility, Aerobatic and Commuter Aeroplanes Amendment 5. https://www.easa.europa.eu/document-library/certification-specifications/cs-23-amendment-5 (accessed 06.06.17).

28 EASA (2012) *CS-27 Small Rotorcraft* Amendment 3. https://www.easa.europa.eu/certification-specifications/cs-27-small-rotorcraft (accessed 03.12.15).

29 International Civil Aviation Organization (ICAO) *Annex 10 to the Convention on International Civil Aviation, Volume IV: Surveillance Radar and Collision Avoidance Systems.*

- RTCA DO-260B/EUROCAE ED-102A with Corrigendum 1, *Minimum Operational Performance Standards for 1090MHz Extended Squitter Automatic Dependant Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast* (TIS-B) December 2011/January 2012[30]

6.6 The specification also reflects Office of Communications (Ofcom) guidance and the findings of QinetiQ's 2015 study *Impact of General Aviation Electronic Conspicuity on TCAS*, which is included as Appendix D to this document.

6.7 When referencing the above documents in relation to the technical specification please refer to the version stated above. If a document revision is deemed to affect this CAP, it will be reviewed and incorporated as necessary.

Requirement for approval of radio communication and radio navigation equipment

6.8 The Air Navigation Order 2016 makes appropriate provisions under the following Articles and Schedules:

a. Article 77(1)(a) requires that an aircraft must not fly unless it is equipped with equipment which complies with the law of the country in which the aircraft is registered or the State of the operator.

b. Article 79(2) requires that the radio station in an aircraft must not be operated so as to cause interference which impairs the efficiency of aeronautical telecommunications or navigational services.

c. Schedule 5, 1(3) states that as regards instruments and equipment not required by this Schedule, including any equipment that is not

30 ED-102A with Corrigendum 1, MOPS for 1090 MHz Extended Squitter Automatic Dependant Surveillance – Broadcast (ADS-B) & Traffic Information Services – Broadcast (TIS-B), EUROCAE, January 2012.
DO-260B with Corrigendum 1, Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependant Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B), RTCA, December 2011

otherwise required by this Order but carried on a flight, the failure or malfunction of such instruments and equipment shall not affect the airworthiness of the aircraft.

6.9 In addition, Commission Implementing Regulation (EU) No 1207/2011 requires that the spectrum used by surveillance systems should be protected to prevent harmful interferences.

6.10 To comply with these requirements, this chapter provides the specification for EC devices as well as guidance on the procedures to be followed to gain CAA approval.

Requirements and recommendations

6.11 Throughout this chapter, there are some requirements that are mandatory for approval and some that are recommended. These are clearly distinguished by the use of the ‘shall’ and ‘should’.

- Where **shall** is used, compliance with the particular requirement, procedure or specification is mandatory and no alternative may be applied.
- Where **should** is used, although the procedure is regarded as the preferred option, alternative procedures, specifications or criteria may be applied, as long as the manufacturer provides information or data to adequately support and justify.

Scope

6.12 EC devices are intended to offer similar functionality to FLARM, but using the 1090MHz airborne spectrum. EC devices are expected to comprise commercial off the shelf (COTS) items such as Software Defined Radios (SDRs), GNSS receiver chipsets and, where applicable, altitude transducers, which are acceptable on the basis that Quality Indicators reported by the device, such as NIC, NAC, GVA, SIL and SDA shall report the lowest quality (refer to Table 4). EC devices may report barometric or GNSS altitude.

6.13 GNSS receivers are available that meet the requirements of FAA TSO-C199 Class B for Traffic Awareness Beacon Systems (TABS), which provide enhanced performance for relatively low cost. These robust receiver designs are capable of providing potential performance enhancements for EC devices, allowing them to report improved functional capability (in terms of position reporting integrity) within allowable limits. The approach taken in TSO-C199 to qualify Class B position sources outlines a path to specify and test a GNSS receiver to a standard that justifies the positional Quality Indicators allowed for such a device.

Therefore, the appropriate elements of compliance demonstration with TSO-C199 may be used to take credit for the benefits offered by Class B position sources. The TSO qualification is regarded as an acceptable means of compliance only and is not formally recognised under the EC device acceptance and approval. Furthermore, the TSO authorisation or letter of TSO design approval and any variations from it **shall** be reviewed as part of the acceptance process.

6.14 EC transcievers are interoperable and may offer some level of interoperability with air traffic services, depending on the capability of the ground infrastructure to receive, process and display the presence of DF=18 capable devices. However, the visibility of such EC devices to air traffic services may depend on the transmitted Quality Indicators. EC devices are not intended to be interoperable with airborne safety nets operating as interrogative collision alerting systems, such as ACAS. This includes TCAS and 'hybrid surveillance'.

6.15 For an EC device to provide a useful level of surveillance capability, it **shall**, as a minimum, transmit Airborne Position, Aircraft Identification and Category and Aircraft Operational Status messages. An EC device may provide additional capability such as, but not limited to, Airborne Velocity and Extended Squitter Aircraft Status Messages. Any additional messages shall conform to the appropriate sections of RTCA DO-

260B/EUROCAE ED-102A (§2.2.3.2). It is anticipated that EC devices will typically provide the messages detailed in Table 1:

Table 1: ADS-B messages

Message	DO-260B/ED-102A section
Airborne position[1]	§2.2.3.2.3
Aircraft Identification and Category	§2.2.3.2.5
Airborne Velocity (Subtype 1)[2]	§2.2.3.2.6.1
Aircraft Operational Status[1]	§2.2.3.2.7.2
Extended Squitter Aircraft Status Message (TYPE Code=28)[2]	§2.2.3.2.7.8

NOTE 1: Surface messages need not be reported.

NOTE 2: May be reported as an option.

6.16 RTCA DO-260B/EUROCAE ED-102A §2.1.12 broadly categorises ADS-B equipment into aircraft equipage classes based on transmitter and receiver capabilities. These system classes are then broken down into subsystem equipment classes, based on individual unit specifications. For portable EC devices, the functionality could conform to transmitting-receive (Class A) and transmit-only (Class B). Given that these are portable low-power devices, Class A0 and B0 are appropriate to their applications. Class A1 has standard transmit power and a more sensitive receiver. Therefore, Class A0 represents the **minimum** in terms of available features for an EC device.

Table 2: ADS-B classes

Interactive aircraft/vehicle participant system (Class A)		
A0	Minimum interactive aircraft/vehicle	Lower transmit power and less sensitive receiver than Class A1
Broadcast-only participant system (Class B)		

B0	Aircraft broadcast only	Transmit power may be matched to coverage needs. Nav. data input required.

6.17 In addition to ADS-B out, portable EC devices may offer the capability of receiving a range of transmission types, including Mode A, C and S transponders and FLARM. Therefore, they may also provide traffic situation displays including visual and audible alerts.

Equipment approval

6.18 Radio equipment used in aircraft is generally non-aircraft specific, and the CAA can approve it under a unique radio approval reference.[31] The CAA issues approvals for such equipment when it is to be installed on non-EASA aircraft or if it is to be carried as a transmitting Portable Electronic Device (T-PED) on-board any aircraft for operation in the UK airspace.

6.19 EC device approval does not cover adaptations to the aircraft necessary to accommodate ancillary equipment such as power provisions, mounting devices or external antennas. Any fixed, ancillary items must still be approved under existing minor modification/change processes and the applicable regulations for the aircraft type. This information **should** also be detailed in the EC device operating manual.

6.20 The paragraphs and tables below specify the requirements and recommendations for manufacturers to follow in the design, construction and testing of an EC device. Manufacturer's substantiation is required to demonstrate to the CAA that:

- the equipment does not affect the safety of persons, or the safe operation of the aircraft by causing interference to other radio users, and

31 More details on radio approval can be found in BCAR Section A, Chapters A4-8 (Accessory Procedure) and A4-10; BCAR Section B, Chapters B4-8 and B4-10. See CAA (1974) *British Civil Airworthiness Requirements Section R – Radio* CAP472. www.caa.co.uk/cap472 (accessed 03.12.15).

- the equipment transmits data that is correct and appropriate for the device.

Equipment approval will only be granted once such substantiation has been received.

6.21 Although considerations for EC device receivers, traffic displays and alerting functions are recommended, these aspects are not directly related to the transmitting function and, therefore, not required as part of the EC device approval. Annex A details acceptable means of compliance (AMC), which amplifies and clarifies aspects of certain requirements and recommendations. In some cases, the AMC softens requirements to recommendations – shall to should – where this would be appropriate for portable EC devices.

6.22 The manufacturer should maintain adequate records covering the manufacture, hardware and software development aspects, test requirements and test results for the EC device and hold these details in an appropriate technical file. To simplify the equipment approval process and make it proportionate for the GA community, the CAA has issued a single approval covering EC devices. For an EC device to be covered by this approval the EC device manufacturer **shall** complete and return to the CAA a Declaration of Capability and Conformance (DoCC) Form SRG1757 together with evidence of payment. The DoCC can be found at www.caa.co.uk/srg1757. The DoCC states that the EC device and its operating manual comply with the specification contained in this chapter. A single DoCC **shall** cover a single device model and does not cover multiple devices from a single manufacturer. If you make a false representation when filling in your declaration you may be committing an offence under UK law.

6.23 Subsequent modifications or changes to the EC device, its hardware or software may be made throughout its product life cycle, however, they **shall** be developed by the device manufacturer only. Such modifications or changes may be made under the following conditions:

- That they do not invalidate the DoCC that was originally accepted by the CAA.
- Subsequent versions of the EC device continue to comply with the requirements of this chapter and Annex A.
- All modifications or changes are documented and held within the manufacturer’s technical file, which will be maintained for the EC device.

If modifications or changes affect aspects of the DoCC equipment capability and conformance section, such as the EC device category or ADS-B messages provided by the device, the manufacturer **shall** complete and return to the CAA a new DoCC. The original DoCC will remain valid for EC devices built before the change or that do not incorporate the change.

6.24 The CAA will record the details of the EC device, its manufacturer and the declaration. The declaration will be reviewed for completeness and if considered satisfactory, the manufacturer will be formally advised that their EC device can be considered as conforming to CAA Equipment Approval LA301076. This is a single approval that will apply to any EC device manufactured according to this process and formally accepted by the CAA.

6.25 An applicant may only claim approval for their EC device after formally being advised by the CAA that the DoCC has been accepted and posted on the CAA ‘General Aviation - Aircraft ownership and maintenance’ web page under Electronic Conspicuity Devices www.caa.co.uk/General-aviation/Aircraft-ownership-and-maintenance/Electronic-Conspicuity-devices/. The manufacturer may then declare that their EC device is covered by CAA Equipment Approval LA301076, which is published on the CAA 'Aircraft equipment’ web page for this purpose at www.caa.co.uk/Commercial-industry/Aircraft/Airworthiness/Aircraft-equipment/Aircraft-equipment/. This is required for EC devices to be legally used onboard an aircraft in UK airspace. The onus is always on the manufacturer to ensure that the consumer can be assured that the device has a valid declaration.

6.26 The CAA will publish a list of manufacturers and devices for which DoCCs have been accepted on its website as an aid to prospective purchasers. This information will also be used by the CAA if it needs to contact manufacturers in the event that the equipment is found to be defective (for example, it is reporting erroneous or misleading data). In such cases:

- The CAA will immediately take reasonable steps to contact the manufacturer and advise them of the issue so that the manufacturer may implement the necessary corrective actions.
- When the manufacturer has been formally advised of the problem, the DoCC for the device will be suspended, removed from the declarations list and this information will be made available on the website to alert device users and other interested bodies, such as the LAA and BMAA that the affected device is no longer covered by a DoCC and can no longer be legally used on an aircraft until the problem is rectified.
- When the manufacturer has resolved the issue to the satisfaction of the CAA, the suspended DoCC may be reinstated, added to the declarations list and details of the suspension removed from the website.
- If the manufacturer is unable to resolve the issue within a reasonable timeframe, the CAA will revoke the affected DoCC, remove it from the declarations list and state that the DoCC is revoked on its website.
- If after reasonable steps to contact the manufacturer the CAA cannot get in contact, the CAA will revoke the affected DoCC, remove it from the declaration list and state that the DoCC is revoked on its website.
- When the manufacturer has resolved the issue to the satisfaction of the CAA, it will be necessary for the device manufacturer to submit a new DoCC and for this to be accepted by the CAA. The DoCC for

the corrected device can then be added to the declarations list on the CAA website.

In all of the above cases, it is the responsibility of the manufacturer to ensure that the technical file that they maintain for the EC device has been updated with the appropriate information on the problem and the steps taken to resolve it.

6.27 Pilots/owners may quote the applicable CAA equipment approval reference when applying to the CAA for a radio licence, as required by the Wireless and Telegraphy Act.[32]

Requirements specification

6.28 Tables 3 and 4 detail the requirements that are applicable to transmitting EC devices. To attain approval, the manufacturer **shall** ensure that the EC device complies with the requirements of the quoted sections and subsections of RTCA DO-260B/EUROCAE ED-102A in full. However, for certain requirements the acceptable means of compliance in Annex A is applicable.

Table 3: Transmitter requirements for portable EC devices

Requirement	Description	AMC (see Annex A)
ICAO Annex 10, Volume IV		
3.1.2.2 Reply Signals-in-Space Characteristics		
3.1.2.2.3	Polarization	Refer to AMC 1391-4.1
3.1.2.8.7 Extended Squitter/Supplementary, Downlink Format 18		
3.1.2.8.7.1[33]	ES supplementary format	
3.1.2.8.9 Extended Squitter Maximum Transmission Rate		
3.1.2.8.9.1	Maximum total number of extended squitter	Refer to AMC 1391-4.2
3.1.2.10 Essential System Characteristics of the SSR Mode S Transponder		

[32] Please see Chapter 3 “Aircraft operator/owner responsibilities and licensing requirements”.
[33] Refer also to RTCA DO-260B/EUROCAE ED-102A 2.2.3.2.1.3.

Requirement	Description	AMC (see Annex A)
3.1.2.10.2.2	Spurious emission radiation	Refer to AMC 1391-4.3
5.1 Mode S Extended Squitter Transmitting System Characteristics		
5.1.1	ADS-B out requirements	Refer to AMC 1391-4.4
RTCA DO-260B/EUROCAE ED-102A		
2.2.2.2 Stand Alone Transmitters		
2.2.2.2.1	Transmission Frequency	
2.2.2.2.2	Transmission Spectrum	
2.2.2.2.3	Modulation	
RTCA DO-260B/EUROCAE ED-102A		
2.2.2.2 Stand Alone Transmitters		
2.2.2.2.4	Pulse Shapes	
2.2.2.2.5	Message Structure	
2.2.2.2.6	Pulse Intervals	
2.2.2.2.7	Preamble	
2.2.2.2.8	Data Pulses	
2.2.2.2.9	Pulse Amplitude	
2.2.2.2.10.3	RF Peak Output Power (maximum)	Refer to AMC 1391-4.5
2.2.2.2.11	Unwanted Output Power	
2.2.2.2.12	Broadcast Rate Capability	
2.2.3 Broadcast Message Rate Characteristics		
2.2.3.1	ADS-B Message Characteristics	
2.2.3.1.1	ADS-B Message Preamble	
2.2.3.1.2	ADS-B Message Data Pulses	
2.2.3.1.3	ADS-B Message Pulse Shape	
2.2.3.1.4	ADS-B Message Pulse Spacing	

Requirement	Description	AMC (see Annex A)
2.2.3.2[a]	ADS-B Message Baseline Format and Structures	Refer to AMC 1391-4.6
2.2.3.2.1.1	"DF" Downlink Format Field	
2.2.3.2.1.3	"CF" Field (used in DF=18)	
2.2.3.2.1.5	"AA" Address Field, Announced	
2.2.3.2.1.6	"ME" Message, Extended Squitter	
2.2.3.2.1.7	"PI" Parity/Identity	
2.2.3.2.2	Determining ADS-B and TIS-B Message Type	
2.2.3.2.3[a]	ADS-B Airborne Position Messages	
2.2.3.2.5	ADS-B Aircraft Identification and Category Messages	Refer to AMC 1391-4.7
2.2.3 Broadcast Message Rate Characteristics		
2.2.3.2.6	ADS-B Airborne Velocity Messages	
2.2.3.2.7.2	Aircraft Operational Status Message	Refer to AMC 1391-4.8
2.2.3.2.7.8	Extended Squitter Aircraft Status Message with TYPE Code=28	Refer to AMC 1391-4.9
2.2.3.3 ADS-B Message Transmission Rates		
2.2.3.3.2	Transmission Rates for Stand Alone Transmitters	
2.2.3.3.2.1	Power-On Initialization and Start Up	
2.2.3.3.2.1.1	Power-On Initialization	Refer to AMC 1391-4.10
2.2.3.3 ADS-B Message Transmission Rates		
2.2.3.3.2.1.2	Start Up	
2.2.3.3.2.2	ADS-B Airborne Position Message Broadcast Rate	

Requirement	Description	AMC (see Annex A)
2.2.3.3.2.4	ADS-B Aircraft Identification and Category Message Broadcast Rate	
2.2.3.3.2.5	ADS-B Velocity Information Message Broadcast Rate	
2.2.3.3.2.6.2	ADS-B Aircraft Operational Status Message Broadcast Rates	
2.2.3.3.2.7	“Extended Squitter Aircraft Status” ADS-B Event-Driven Message Broadcast Rate	
2.2.3.3.2.9	ADS-B Message Transmission Scheduling	
2.2.3.3.2.9.1	Scheduling of Non Event-Driven Messages	
2.2.3.3.2.9.2	Event-Driven Message Scheduling	
2.2.3.3.2.10	Maximum ADS-B Message Transmission Rates	
2.2.3.3.2.11	ADS-B Message Timeout	
2.2.3.3.2.12	ADS-B Message Termination	
2.2.3.4	ADS-B Transmitted Message Error Protection	
2.2.5	ADS-B Transmission Device Message Processor Characteristics	Refer to AMC 1391-4.11 and 4.12

a: Refer to Table 4 and 5 for accuracy and integrity metrics settings.

Quality Indicator reporting

6.29 The Quality Indicators **shall** be reported by the EC device as detailed in Table 4.

Table 4: Quality Indicator settings according to the position source

Quality Indicator	COTS position source	TABS Class B position source	RTCA DO-260B/ED-102A section	FAA TSO-C199
	Required setting	Required setting		
Airborne Position TYPE Code (with Baro Altitude)	18	13 to 18 depending on NIC	2.2.3.2.3.1	-
Airborne Position TYPE Code (with GNSS Height (HAE))	22	22	2.2.3.2.3.1	-
NIC	ZERO	Up to 6 (R_C < 0.5 NM / 925 m)	2.2.3.2.2 and 2.2.8.1.1.6	A1.2.5.6
NIC Supplement-A	ZERO	Depends on NIC	2.2.3.2.7.2.6	-
NIC Supplement-B	ZERO	Depends on NIC	2.2.3.2.3.3	-
NIC Supplement-C	Not used	Not used	2.2.3.2.7.2.3.10	-
NIC_{BARO}	ZERO	ZERO	2.2.3.2.7.1.3.9 and 2.2.3.2.7.2.10	-
NAC_P	ZERO/depends on HFOM	Depends on HFOM	2.2.3.2.7.1.3.8 and 2.2.3.2.7.2.7	A1.2.5.8
NAC_V	ZERO	1 (10 m/s)	2.2.3.2.6.1.5 and 2.2.3.2.7.2.3.8	A1.2.5.9

Quality Indicator	COTS position source	TABS Class B position source	RTCA DO-260B/ED-102A section	FAA TSO-C199
	Required setting	Required setting		
GVA	ZERO	Depends on VFOM	2.2.3.2.7.2.8	A1.2.5.10
SIL	ZERO	1 (1x10^{-3}/hr)	2.2.3.2.7.1.3.10 and 2.2.3.2.7.2.9	A1.2.5.6
SIL Supplement	ZERO	ZERO	2.2.3.2.7.1.3.1 and 2.2.3.2.7.2.14	-
SDA	ZERO	1	2.2.3.2.7.2.4.6	A1.2.5.7 SDA **shall** be set to 1 for an EC device

Recommendations for all portable EC devices

6.30 Table 6 details general recommendations that are applicable to all EC devices, whether they are transmitting or transmitting and receiving types. EC devices manufacturer **should** comply with the quoted sections and subsections of Table 6 in full.

Table 5: Recommendations for all portable EC devices

Requirement	Description	AMC (see Annex A)
ICAO Annex 10, Volume IV		
2.2.1 Operation of controls		
2.2.1.1	Transponder controls which are not intended to be operated in flight	Refer to AMC 1391-4.13
RTCA DO-260B/EUROCAE ED-102A		
2.2.16 Compatibility with Other Systems		
2.2.16.1	EMI Compatibility	Refer to AMC 1391-4.14
4.0 Operational Characteristics and Functional Requirements		
4.3	Self Test	Refer to AMC 1391-4.15
4.3.2.3	Failure Annunciation	
4.4	Controls	
UL 1642, UL 2054, UL 60950-1		
UL 1642	Lithium Batteries	Refer to AMC 1391-4.16
UL 2054	Household and Commercial Batteries	
UL 60950-1	Information Technology Equipment – Safety	
IEC 62133	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications	

Receiver recommendations for portable EC devices

6.31 Table 7 details recommended considerations for EC device receivers, traffic displays and alert functions. Although these aspects are not directly related to the transmitting function and therefore not directly covered by the EC device approval, the manufacturer **should** consider these aspects and their impact on the device and its user.

Table 6: Recommended considerations for EC device receivers, traffic displays and alerting functions

Requirement	Description	AMC (see Annex A)
RTCA DO-260B/EUROCAE ED-102A		
2.2.4	ADS-B Receiver Characteristics	
2.2.6	ADS-B Receiver Device Message Processor Characteristics	
2.2.7	ADS-B Message Processor Characteristics	
2.2.8	ADS-B Report Characteristics	
2.2.9	ADS-B Report Type Requirements	
2.2.10	ADS-B Receiver Report Assembly and Delivery	
2.2.16	Compatibility with Other Systems	

6.32 Where the device provides visual indications of airborne traffic hazards, either by the use of lights or a dedicated traffic display, the colours used for such visual indications or symbology **should** be consistent with xx.1322 of EASA CS 23, CS 27, BCAR Section T, BCAR Section VLH or other appropriate airworthiness codes. They **should** also be distinguishable from other cockpit displays and effective under all anticipated lighting conditions for the intended aircraft.

6.33 Where the device provides audible alerts of airborne traffic hazards, these **should** be of a manner and sound level that makes them audible and distinguishable from other alerts and effective under all anticipated noise levels for the intended aircraft.

Testing

6.34 Table 8 details recommended tests for EC devices. The EC device manufacturer **shall** ensure that appropriate tests are conducted to prove that the EC device transmits the available data according to the appropriate message formats. Tests **should** be carried out with due regard to the RTCA DO-260B/EUROCAE ED-102A subsections detailed in Table 8, or in a manner acceptable to the CAA that establishes appropriate EC device functioning.

Table 7: Recommended EC device tests

DO-260B/ED-102A subsection	Description
2.4.2.2	Verification of Stand Alone Transmitters (to §2.2.2.2)
2.4.3.1	Verification of ADS-B Message Characteristics (to §2.2.3.1)
2.4.3.2	Verification of ADS-B and TIS-B Message Baseline Format Structures (to §2.2.3.2)
2.4.3.3	Verification of ADS-B Transmission Rates (to §2.2.3.3)
2.4.5	Verification of ADS-B Transmission Device Message Processor Characteristics (to §2.2.5)

Requirements for the EC device operating manual

6.35 The following is a summary of the information that shall be included in the EC device operating manual:

- the requirement and instructions for setting up the ICAO 24 bit address for the aircraft that the EC device is being carried on;
- instructions to deactivate the EC device transmitter when the EC device is used on an aircraft with an air traffic control radar beacon system (ATCRBS) or Mode-S transponder;
- instructions for mounting the EC device antenna(s) so that they do not compromise the operation of any other proximate communication or navigation antenna or system;
- instructions on how to set up the device antenna in such a way that it provides as near vertical polarisation as possible, thereby allowing the EC device to operate at its intended, optimal performance level;
- instructions for carrying out a pre-flight cross-check of the reported altitude against the aircraft altimeter if appropriately equipped;
- a warning that it is the responsibility of the pilot to ensure that the EC device causes no harmful interference to other on-board equipment and systems;

- appropriate warnings highlighting the risks of pilot distraction caused by accessing and altering configurable options, which are not intended to be operated in flight;
- appropriate warnings that the EC device should be regarded as an aid to the ‘see and avoid’ principle, and that manoeuvres to regain adequate separation should not be based on alerts issued by the EC device alone;
- information that EC device approvals do not cover adaptations to the aircraft necessary to accommodate ancillary equipment such as power provisions, mounting devices or external antennas, and that such items must still be approved under existing minor modification/change processes applicable to the aircraft type; and
- details of the battery type to be used in case routine replacement is possible by the owner.

Annex A

Acceptable means of compliance

1. This annex amplifies and clarifies certain parts of the requirements and offers some alleviations, which are designed to help manufacturers establish compliance with the technical specification requirements above, where appropriate. It **shall** be read in conjunction with the technical specification.

AMC 1391-4.1: Polarisation

The operating manual **should** contain sufficient information to allow the user to set up the device antenna in such a way that it provides vertical polarisation and thereby effectively allows the EC device to operate at its intended, optimal performance level.

AMC 1391-4.2: Maximum total number of extended squitters

The maximum total number of DF=18 extended squitters emitted by the device **shall not** exceed:

a. 6.2 messages per second, averaged over 60 seconds, for nominal aircraft operations with no emergency activity, while not exceeding 11 messages being transmitted in any 1-second interval (partially addressed by RTCA/DO-260B §2.2.3.3.3.2.10), or
b. 7.4 messages per second, averaged over 60 seconds, under an emergency condition, while not exceeding 11 messages being transmitted in any 1-second interval.

AMC 1391-4.3: Spurious emission radiation

It is recommended that for the ADS-B transmitting device, continuous wave (CW) radiation **should not** exceed 70 dB below 1 watt.

AMC 1391-4.4: ADS-B out requirements

Due to the reduced transmitter power of EC devices covered by this requirement, it is accepted that the minimum air-to-air range specified in ICAO Annex 10, 5.1.1.3 for extended squitter transmitting and receiving systems in the classes specified, may not be supported.

AMC 1391-4.5: RF peak output power (maximum)
The maximum RF peak output power of each pulse of each transmitted message at the antenna terminals of the EC device **shall not** exceed 16 dBW (40W). The operating manual **should** contain sufficient information to allow the user to set up the device antenna in such a way that it effectively allows the EC device to operate at its intended, optimal performance level.

AMC 1391-4.6: ADS-B message baseline format and structures
ADS-B messages **shall** use Extended Squitter format for DF = 18 transmissions in which CF=0 or 1 (that is, DF=18 Extended Squitters that carry ADS-B messages).

AMC 1391-4.7: ADS-B Aircraft Identification and Category Messages
The device **shall** have the facility to programme/reprogramme the ICAO 24 bit address. Manufacturers **should** instigate means to mitigate incorrect 24 bit entry, eg the 24 bit address would only be accepted and stored by the device after being entered correctly twice. A function **should** also exist to clear the programmed 24 bit ICAO address and to alert the user if no ICAO 24 bit address has been entered. Full instructions on how to complete these tasks **shall** be contained within the device operating manual.

AMC 1391-4.8: Mode A Code 1000
Refer to RTCA DO-260B/EUROCAE ED-102A §2.2.3.2.7.8.1.2.

If the EC device has a facility to transmit a Mode A code and code 1000 is set, then manufacturers **shall** ensure that the broadcast of Mode A code information by the EC device is inhibited.

AMC 1391-4.9: Extended Squitter Aircraft Status Message with TYPE Code=28
If the EC device supports Extended Squitter Aircraft Status Message TYPE Code=28 for “Emergency/Priority Status” Subfield and/or “Mode A (4096) Code” Subfield in Aircraft Status Messages, the device **should** comply with RTCA DO-260B/EUROCAE ED-102A §2.2.3.2.7.8.1.1 and/or §2.2.3.2.7.8.1.2 respectively.

AMC 1391-4.10: Power-on initialization

RTCA DO-260B/EUROCAE ED-102A §2.2.3.3.2.1.1 a and b are applicable, but c is not applicable. For b, given that appropriate message data is provided to the ADS-B Transmit stage, the EC device, **should** be capable of transmitting ADS-B messages within a reasonable time period after power-on.

AMC 1391-4.11: ADS-B Transmission Device Message Processor characteristics

The EC device **should** process the available data and format the appropriate messages in accordance with the relevant subsections of RTCA DO-260B/EUROCAE ED-102A §2.2.5.1.

AMC 1391-4.12: Altitude data

Refer to RTCA DO-260B/EUROCAE ED-102A §2.2.5.1.5 a. for pressure altitude or b. for GNSS HAE.

It is envisaged that a Basic/transmit-only device would report GNSS height, whereas a more elaborate Intermediate device may use a barometric altitude sensor. Suitable provision to set up an EC device incorporating a barometric altitude sensor **should** be made, i.e. as part of a status display. Also, the operating manual should provide sufficient information for this to be practically achievable.

a. In line with ICAO Annex 10, Vol. IV, 3.1.1.7.12.2.4, if a pressure altitude sensor is incorporated in the EC device, it **shall** provide altitude data corresponding to within +/- 38.1 m (125 ft) with the pressure-altitude (referenced to the standard pressure setting of 1013.25 hectopascals) on-board the aircraft.

b. The transmitting device **should** correctly report the altitude resolution (quantisation) used according to RTCA DO-260B/EUROCAE ED-102A §2.2.3.2.3.4.3.

c. If fitted with a display, the EC device **should** provide a means for displaying the barometric altitude data being transmitted and the operating manual **should** contain instructions for carrying out a cross-check of the reported altitude against the aircraft altimeter if applicable.

If capable, the EC device may provide GNSS Height Above the Ellipsoid (HAE) in accordance with RTCA DO-260B/EUROCAE ED-102A §2.2.5.1.5 b.

AMC 1391-4.13: Transponder controls which are not intended to be operated in flight

It is recommended that all EC device configurable options which are **not** intended to be operated in flight **should not** be easily accessible to the pilot. It **should not** be necessary to access or modify such configurable settings during normal device operation, so preventing inappropriate operation or pilot distraction. If this feature cannot be incorporated, appropriate warnings **should be** incorporated into the EC device operating manual highlighting the risks. (It is recognised in the context of this requirement that EC devices are not transponders.)

AMC 1391-4.14: EMI compatibility

All EC device operating manuals **should** contain instructions on how to:

- deactivate the EC device transmitter when the EC device is used on an aircraft with an ATCRBS or Mode-S transponder;
- mount the device antenna(s) so that it does not compromise the operation of any other proximate antenna or system;
- carry out checks to ensure that the EC device does not compromise the operation of any co-located communication or navigation equipment.

It is the responsibility of the operator to ensure the EC device causes no harmful interference to other onboard equipment.

Control of interference is, to some extent, mitigated by ICAO Annex 10, Vol. IV 3.1.2.10.2.2. The Radio Equipment Directive 2014/53/EU (RED) was published on 22 May 2014 and becomes effective on 13 June 2016, when the existing Radio & Telecommunications Terminal Equipment Directive 1999/5/EC (R&TTED) will be repealed. Directive 2014/53/EU applies to equipment placed on the market, which intentionally transmits or receives radio waves for communication or radio determination (equipment that uses the propagation qualities of radio waves to determine its position). However, Annex 1 point 3 to this regulation states that airborne products, parts and appliances falling within the scope of Article 3 of

Regulation (EC) No 216/2008 are not covered by this directive. Regulation (EC) No 216/2008 Article 3 (d) covers equipment, mechanism, part, apparatus, appurtenance, software or accessory including communications equipment that is used or intended to be used in operating or controlling an aircraft in flight.

Therefore, although not required, manufacturers are recommended to test devices to an appropriate European Telecommunications Standards Institute (ETSI) standard. Examples may include, but are not limited to:

- EN 300 440-2 - Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Part 2: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive
- EN 301 489-1 - Electromagnetic Compatibility and Radio Spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements for the appropriate class, device and equipment type, or an equivalent acceptable standard
- EN 301 489-3 - Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 3: Specific conditions for Short-Range Devices (SRD) operating on frequencies between 9 kHz and 246 GHz

AMC 1391-4.15: Operational characteristics and functional requirements

It is recognised that EC devices will not be subject to routine maintenance and tests throughout their lifecycle in the same way that conventional avionics equipment would be. Therefore, the option of providing a simple form of built-in confidence checking and failure detection and indication, if the device is capable of supporting these, is highly recommended.

It is highly recommended that a means be provided for the operator to establish confidence that the EC device is functioning correctly.

The EC device **should** also incorporate some means of monitoring and alerting the operator to any failure condition associated with the transmission of erroneous data, for example data which indicates that the participant address or 24-bit aircraft address is all zeroes or all ones.

AMC 1391-4.16: Lithium batteries

It is highly recommended that non-rechargeable and rechargeable lithium batteries used to power EC devices comply with the standards specified in Table 6 of the technical specification or are designed in such a way that they meet the intent of those standards in relation to construction, performance and tests to ensure reduction of risk of fire or explosion. The EC device manufacturer should specify the battery type to be used in the EC device operating manual in case of routine replacement by the owner.

Chapter 7

Conclusion

7.1 'See and avoid' is a fundamental principle of aircraft operations. It relies on airspace users maintaining a good lookout, but even if this is done, there are limits on the effectiveness of visual scan. A body of evidence exists that EC devices can be used as an aid to 'see and avoid' by enhancing situational awareness through supplementary cues. In this context, the 'see-and-avoid' concept may be considered as a 'See, BE SEEN, and avoid' concept.

7.2 The ECWG concluded that increased EC for users of Class G airspace could improve safety through enhanced situational awareness. The members considered that it might be possible to produce a low-cost EC device, with sufficient potential safety benefits to encourage significant voluntary equipage among the GA community. The ECWG subsequently commissioned the CAA EC project. The publication of this civil airworthiness publication (CAP) is one of the outcomes of the project.

7.3 This CAP is aimed at potential manufacturers of EC devices as well as the wider GA operator community. It fulfils two key requirements of the project:

- producing Technical Specification Requirements (and associated AMC) for EC devices
- providing assurance that EC devices manufactured to these specifications will not compromise the performance of air to air or air to ground safety nets.

It also summarises the licensing requirements for aircraft owners/ operators wishing to purchase such EC devices.

7.4 It was recognised at the outset that owners/operators will have differing requirements and that there would therefore be a requirement for a tiered capability for EC devices (defined here as Basic, Intermediate and Full). By defining minimum requirements only, this CAP aims to give manufacturers the technical detail and certainty they need, without being overly prescriptive. It is hoped that this will encourage the market to develop and produce a range of devices of differing capabilities – which in turn can serve to drive down costs and encourage maximum uptake by owners/operators.

7.5 The delivery of the EC project and the development of the resulting CAP have been a truly collaborative endeavour, with notable input and support provided by all the relevant stakeholders via the memberships of the ECWG and CWG, who defined the required project outcomes and critically challenged developing thinking and outputs. The Department for Transport provided the essential funding to support the project, there were also significant resources provided by the ECWG and CWG members.

7.6 Further work will be required in the field of EC. Moving forward, the CWG, with its wide range of GA community stakeholders and technical subject matter experts, will remain the principal forum for discussing EC-related issues and will determine future work priorities. However, at this stage, the original aim has been fulfilled, with the development of an industry standard for an EC device.

Appendix A

Comparison of current surveillance systems

Table 8: Comparison of current surveillance system

System	Installed/ Portable	Interoperability	Equipment qualification level	
ACAS II	Installed	ACAS II, ACAS I, TAS, Mode C and S, TABS, ADS-B, ATC (RA downlink)	(E)TSO-C119()	EUROCAE ED-143, ED-144, ED-221
ACAS I	Installed	ACAS II, ACAS I, TAS, Mode C and S, TABS, ADS-B	TSO-C147	RTCA/DO-197A
TAS	Installed			
TABS	Installed		TSO-C199	Various available RTCA MOPS
Mode A, C		ACAS II, ACAS I, TAS, TABS, ATC	TSO-C47()	EUROCAE ED-43 RTCA/DO144A
Mode S ELS	Installed	ACAS II, ACAS I, TAS, TABS, ADS-B, ATC	ETSO-C112()	EUROCAE ED-73E
Mode S EHS	Installed			
1090 ES ADS-B out/in (DF 17)	Installed	ACAS II, ACAS I, TAS, TABS, Mode S, ADS-B, ATC	ETSO-C166b	DO-260B
FLARM	Portable or installed	FLARM, PowerFLARM offers the options of ADS-B, Mode C and S (receive only)	Commercial and European R&TTE Directive. EASA AML STC applies for installed systems for aircraft <2000 kg.	
EC devices (DF 18)	Portable	EC devices, ADS-B (DF 18), ATC. Option of FLARM Mode A, C and S (receive only)	CAA Aircraft Equipment Approval LA301076. Appropriate ETSI standard (optional).	

Appendix B

Abbreviations

AAIB	Air Accidents Investigation Branch
ACAS	ACAS
ADS-B	Automatic Dependant Surveillance – Broadcast
AMC	Acceptable means of compliance
ANSP	Air navigation service provider
ASI	Airspace and Safety Initiative
ASI ECWG	Airspace and Safety Initiative Electronic Conspicuity Working Group
ATC	Air traffic control
ATCRBS	Air Traffic Control Remote Beacon System
ATS	Air traffic services
BCAR	British Civil Airworthiness Requirements
CAP	Civil Airworthiness Publication
CF	Control Field
CS	Certification Specification
CWG	Conspicuity Working Group
DF	Downlink Format
EC	Electronic conspicuity
ECWG	Electronic Conspicuity Working Group
EMI	Electromagnetic interference
ERM	Electromagnetic Compatibility and Radio Spectrum Matters
ES	Extended squitter
EUROCAE	European Civil Aircraft Equipment
FRTOL	Flight Radio Telephony Operators Licence
GA	General aviation
GPS	Global positioning system
GNSS	Global Navigation Satellite System
GVA	Geometric Vertical Accuracy
HAE	Height Above the Ellipsoid
ICAO	International Civil Aviation Organisation

IEC	International Electrotechnical Commission
IFF	Identification Friend or Foe
LAA	Light Aircraft Association
MAC	Mid-air collision
ME	Message Extended
MHz	Megahertz
NAC_P	Navigation Accuracy Category for position
NAC_V	Navigation Accuracy Category for velocity
NIC	Navigation Integrity Category
NISC	National IFF/SSR Committee
Ofcom	Office of Communications
RA	Resolution Advisories
RF	Radio frequencies
RTCA	Radio Technical Commission for Aeronautics
Rx	Receive
SARG	Safety and Airspace Regulation Group
SDA	System Design Assurance
SIL	Source Integrity Level
SSR	Secondary Surveillance Radar
TCAS	Traffic alert and Collision Avoidance System
TIS-B	Traffic Information Services – Broadcast
Tx	Transmit
UL	Underwriters Laboratories
UKAB	United Kingdom Airprox Board
WTA	Wireless Telegraphy Act

Appendix C

Glossary

ACAS II Traffic Advisory (TA)	Audible and visual information provided in the cockpit to advise pilots of the position of a potential threat aircraft.
ACAS II Resolution Advisory (RA)	Audible and visual information provided in the cockpit to advise pilots that a particular vertical manoeuvre should, or should not, be performed to maintain safe separation from a threat aircraft.
Automatic Dependent Surveillance – Broadcast (ADS-B)	ADS-B is a surveillance application transmitting parameters, such as position, track and ground speed, via a broadcast mode data link, at specified intervals, for utilisation by any air and/or ground users requiring it. ADS-B is a data link application. [ICAO Doc 9694]
ADS-B Message	A modulated packet of formatted data that conveys information used in the development of ADS-B reports.
ADS-B Report	Specific information provided by ADS-B participants. Reports contain identification, state vector, and status/intent information. Elements of the ADS-B Report that are used and the frequency with which they must be updated will vary by application. The portions of an ADS-B Report that are provided will vary by the capabilities of the transmitting participant.
Aircraft proximity	A situation in which, in the opinion of a pilot or air traffic services personnel, the distance between aircraft as well as their relative positions and speed have been such that the safety of the aircraft involved may have been compromised. [ICAO Doc 4444]
Airprox	The code word used in an air traffic incident report to designate aircraft proximity. [ICAO Doc 4444] *Note the CAA CAP 493 (MATS) defines 'An AIRPROX' using the ICAO Doc 4444 'Aircraft Proximity' definition text.*
Air traffic service (ATS)	A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service). [ICAO Doc 4444]
Airborne collision avoidance system (ACAS)	An aircraft system based on secondary surveillance radar (SSR) transponder signals that provides pilots with an independent means of visual acquisition and alerting of other SSR transponder equipped aircraft that pose potential collision hazards. ACAS II additionally provides advice to pilots on vertical manoeuvres so that adequate separation may be maintained or achieved between potentially conflicting aircraft.
Class G airspace	*Class G.* IFR and VFR flights are permitted and receive flight information service if requested. All IFR flights shall be capable of

	establishing air-ground voice communications. A speed limitation of 250 kts IAS applies to all flights below 3050 m (10 000 ft) AMSL, except where approved by the competent authority for aircraft types, which for technical or safety reasons, cannot maintain this speed. ATC clearance is not required. [SERA.6001 Classification of airspaces]
Downlink Format (DF) 18	The "DF" field is the first field in the downlinked ADS-B message that defines the data exchanges. DF 18 is used for all ADS-B messages from transmission devices that are not Mode S transponder based systems.
Extended squitter	A squitter incorporating an additional 56 bit data field used to carry ADS-B information.
FLARM	A collision avoidance system that predicts own aircraft short-term future flight path and continuously transmits this to nearby aircraft using an encrypted digital radio message. FLARM-compatible systems in nearby aircraft receive these radio messages and respond with their data. As such, aircraft locations are known, flight paths calculated and alerts issued when the predicted trajectories suggest a collision risk. A data connection allows other aircraft to be shown on external displays.
General aviation	General aviation is defined, for statistical purposes, as all civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire
Squitter	The transmission of messages that conform to a specific format that are generated at periodic rates without the need for the participant transmitter to be interrogated
Traffic Alert and Collision Avoidance System (TCAS)	A specific implementation of the ACAS (Airborne Collision Avoidance System) concept. TCAS II version 7.0 and 7.1 are currently the only available equipment that is fully compliant with the ACAS II ICAO Standards and Recommended Practices (SARPs).
Transponder	A device that emits an identifying signal as well as other information in response to receiving an interrogation signal.
Uncontrolled airspace	Uncontrolled airspace is a generic term that covers ATS airspace Classes F and G as described in ICAO Annex 11 2.6
VFR	'VFR' means the symbol used to designate the visual flight rules. [Commission Implementing Regulation (EU) No 923/2012 of 26 September 2012]
VFR Flight	'VFR flight' means a flight conducted in accordance with the visual flight rules [Commission Implementing Regulation (EU) No 923/2012 of 26 September 2012]
Visual flight rules	See SERA Section 5 Visual meteorological conditions, visual flight rules, special VFR and instrument flight rules; and The Rules of the Air Regulations 2015.

Appendix D

Impact of General Aviation Electronic Conspicuity on TCAS

QinetiQ

Modelling Request: Impact of General Aviation Electronic Conspicuity on TCAS
Issue 1.0

A Peaty and H Hutchinson
QINETIQ/15/02265
20th November 2015

CONDITIONS OF SUPPLY

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Abstract

The Electronic Conspicuity Working Group has identified a potential requirement for an affordable Automatic Dependent Surveillance – Broadcast (ADS-B) Out capable device for General Aviation (GA) users, which will employ 1090 MHz Extended Squitter with the aim of improving GA safety and to help mitigate the risk posed by infringements of controlled airspace. However, there is European Union (EU) legislation in place to ensure that the Interrogator Friend or Foe (IFF) / Secondary Surveillance Radar (SSR) spectrum is protected from interference that could harm the performance of current SSR systems.

There has already been work undertaken that shows that the introduction of significant numbers of ADS-B Out equipped GA aircraft would have minimal effect on the ability of ground surveillance systems to detect existing transponder-equipped aircraft. However, to date, there has not been a study to analyse the effect that ADS-B Out equipped GA aircraft could have on Traffic alert and Collision Avoidance System (TCAS) equipped aircraft.

This study analyses the effects that significant numbers of ADS-B Out equipped GA aircraft have on TCAS II equipped aircraft within the London terminal control area (known as the LTMA). The study concludes that these devices would have a minimal effect on the ability of the TCAS II to operate.

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1 Introduction

1.1 Contractual Matters

This Report has been prepared by the Air Traffic Management (ATM) team at QinetiQ Malvern, for the Civil Aviation Authority (CAA) under contract number 2351.

1.2 Aim

The aim of this Study is to provide the CAA with an analysis of the effects that Electronic Conspicuity (EC) devices could have on Traffic alert and Collision Avoidance System (TCAS) II equipments.

1.3 Background

The EC Working Group has identified a potential requirement for an affordable Automatic Dependent Surveillance – Broadcast (ADS-B) Out capable device for General Aviation (GA) users, which will employ 1090 MHz Extended Squitter with the aim of improving GA safety and to help mitigate the risk posed by infringements of controlled airspace. However, there is European Union (EU) legislation [1] in place to ensure that the Interrogator Friend or Foe (IFF) / Secondary Surveillance Radar (SSR) spectrum is protected from interference that could harm the performance of current SSR systems. To enable the introduction of GA EC devices, assurance must be provided that any system introduced does not cause:

1. Interference that compromises the performance of air-to-air safety nets (*i.e.* TCAS);
2. Interference that compromises the performance of the ground surveillance infrastructure;
3. Loss of separation between aircraft that require an ATC separation service.

QinetiQ has undertaken work for NATS [2], via the National IFF/SSR Committee (NISC), which shows that the introduction of significant numbers of ADS-B Out equipped GA aircraft would have minimal effect on the ability of the ground surveillance system to detect existing transponder-equipped aircraft. This work was undertaken using the initial SSR/IFF Environmental Model (SIEM1) which is used by the NISC to determine the effects of new systems on the UK IFF/SSR Radio Frequency (RF) environment.

NATS has advised CAA that the risk associated with the loss of separation between aircraft that require an Air Traffic Control (ATC) separation service can be mitigated through ATC procedures. ATC does not plan at present to provide a separation service to aircraft solely equipped with an EC device.

These both being the case, it is still necessary to determine whether the introduction of EC devices in significant numbers could compromise the performance of air-to-air safety nets.

1.4 Scope

This Study examines the effect that EC devices are expected to have on TCAS II equipment by analysing the interference effects on selected TCAS II equipments'

Probability of Detection, Round Trip Probability and FRUIT[1] levels. The EC devices are modelled as being compliant with RTCA DO-260B [3] / EUROCAE ED-102A [4] definitions of Non-Transponder Devices. Transmission powers are modelled as varying between 10W and 70W.

1.5 Configuration of Software versions

SIEM2 version 1.1.0.0 was used for the modelling.

1.6 Adoption of SIEM2

This work relies on the use of SIEM2, the upgraded version of the SIEM1 model. The SIEM1 model has been used on behalf of the NISC to analyse the RF environment for over twenty-five years and over this time has been validated for use. However, SIEM1 does not have the capability to analyse the effects of EC devices on TCAS II equipment as it is not capable of outputting the necessary results for TCAS equipment.

SIEM2 was developed in 2014 according to a set of Threshold and Objective Measures Of Performance (MOP) agreed by the MOD [5]. These defined the required accuracy of specific metrics output by SIEM2 in terms of the same metrics output by SIEM1 for the same scenario (*i.e.* equivalence requirements). The Threshold MOP was for SIEM2 results to be within 2% of the SIEM1 metrics for average Probability of Detection and average Transponder Availability. The Objective MOP was for SIEM2 results to be within 1% for the same SIEM1 metrics.

During the Factory Acceptance Tests [6], QinetiQ determined that SIEM2 had met the requirements sufficiently to be at an acceptable standard and recommended its adoption by the NISC.

However, it has been noted by the NISC that SIEM2 has not been subjected to the intense use that could be expected to fully validate the new model and so there is the possibility that input parameters may not be set optimally and that there still remains the possibility of errors in the coding.

[1] False Replies Unsynchronised In Time

2 Effect of EC devices on TCAS II

2.1 Introduction

Standards for TCAS II[2] are published by the International Civil Aviation Organization (ICAO) as 'Standards and Recommended Practices' (SARPs) for Airborne Collision Avoidance Systems (ACAS) [7], and jointly by RTCA and EUROCAE as 'Minimum Operational Performance Standards' (MOPS) [8].

TCAS can detect and track only those aircraft equipped with a transponder operating Mode C or Mode S.

The use of the 1030/1090 MHz spectrum by TCAS equipped aircraft, beyond that resulting from their equipage with a Mode S transponder, is outlined below. More details can be found in the TCAS standards mentioned above and in the ICAO 'ACAS Manual' [9].

2.2 Active Surveillance

2.2.1 Mode C targets

Mode C targets are detected as replies to a 'Mode C all-call' interrogation sent by the TCAS system (in a series of whisper-shout sequences, to reduce synchronous garbling of replies) once per surveillance update cycle (which is nominally one second). A suppression pulse in the interrogation ensures that Mode S equipped aircraft do not reply to these interrogations (*i.e*. an Intermode C interrogation with a Short P4 pulse).

The replies consist solely of the Mode C reported barometric altitude (there is no indication of the identity of the interrogated aircraft).

The replies are either associated with established tracks maintained by the TCAS system or used as the basis for initiating a new track. Tracks can be coasted for up to six seconds. After this time, tracks for which no new replies have been detected will be dropped.

2.2.2 Mode S targets

Mode S targets are acquired by TCAS when it receives a Downlink Format 11 (DF=11), as transmitted by other Mode S aircraft. These transmissions can be replies to a 'Mode S all-call' interrogation sent by a ground based system, or spontaneous 'acquisition squitters' made periodically (approximately once per second) by all Mode S equipped aircraft.

Additionally, some TCAS systems may detect Mode S targets by receiving the DF=17 transmissions of other aircraft. These transmissions are spontaneous 'Extended Squitters' made periodically (approximately twice per second) by capable aircraft. The capability to detect Mode S targets by DF=17 transmissions may become a requirement for TCAS systems in the future.

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[2] For convenience henceforth referred to in this report as 'TCAS'.

For newly acquired targets, TCAS attempts to determine their altitude through passively monitoring DF=0 (broadcast in response to TCAS surveillance interrogations from other TCAS aircraft) and DF=4 (broadcast in response to ground surveillance interrogations) transmissions. If the altitude indicates that the target is within 10,000 ft relative altitude of own aircraft, or the altitude cannot be determined, then TCAS sends an addressed Uplink Format 0 (UF=0) interrogation to that aircraft. From the DF=0 reply the range, bearing, and altitude of the target are determined.

A target for which a track has already been established is periodically interrogated with an addressed UF=0 interrogation eliciting a DF=0 reply.

2.3 Passive Surveillance

Mode S equipped aircraft with an Extended Squitter capability periodically and spontaneously broadcast ADS-B transmissions using DF=17, containing position data derived from an on-board navigation source.

The most recent TCAS specification (version 7.1) permits an optional way of passively tracking certain Mode S targets through their ADS-B transmissions; a technique known as 'Hybrid Surveillance'.

The intent of Hybrid Surveillance is to reduce the TCAS Mode S interrogation rate through the judicious use of validated ADS-B data from other aircraft provided via the Mode S Extended Squitter without any degradation of the safety and effectiveness of TCAS. Standards for Hybrid Surveillance have been published in RTCA MOPS [10].

TCAS units equipped with Hybrid Surveillance use passive surveillance instead of active surveillance to track intruders that meet validation criteria and are not projected to be near-term collision threats.

Hybrid Surveillance is only applied to those Mode S targets that have been acquired through the normal means indicated above. TCAS periodically validates the ADS-B replies by actively interrogating the Mode S target and comparing the measured position with the ADS-B position.

Active interrogations are used to track any intruder which is diagnosed as a threat, and any aircraft for which the periodic validation indicates that the ADS-B position information is unreliable.

2.4 TCAS coordination

When TCAS diagnoses that another aircraft constitutes a threat requiring a Resolution Advisory (RA) to be issued, then the vertical senses of the RAs on both aircraft in the conflicting pair are coordinated. This coordination is achieved via a Resolution Advisory Complement (RAC) contained in a Coordination Interrogation UF=16 message sent by the aircraft issuing the RA, addressed to the threat aircraft.

The threat aircraft acknowledges receipt of the Coordination Interrogation by replying with a Coordination Reply DF=16 message.

2.5 ACAS Broadcast

TCAS aircraft periodically make an 'ACAS Broadcast' which announces their Mode S address and TCAS capability. Although using an interrogation format (UF=16) the ACAS Broadcast does not cause other aircraft to reply: certain bits within the ACAS Broadcast are set so as to indicate that the interrogation does not require a reply. Other TCAS aircraft monitor these ACAS Broadcasts to keep a count of the number of TCAS interrogators in the vicinity.

This count of TCAS aircraft is used by each TCAS to limit the power and number of its own interrogations through 'Interference Limiting', with the aim of preventing unacceptable degradation in the availability of aircraft transponders to ground-based ATC radar.

2.6 Effect of Electronic Conspicuity devices on TCAS

The summary provided in the previous sections indicates that TCAS makes no use of DF=18 messages. Consequently, EC devices such as those envisaged (*i.e.* devices that broadcast only, using DF=18 format messages) will, when operating at rates specified by international standards, have no effect on the operation of TCAS. They will effectively be invisible to TCAS.

TCAS using Hybrid Surveillance – which uses Extended Squitter messages to build up an air picture – should also not use DF=18 messages. Hybrid Surveillance only uses Extended Squitter information to reduce the amount of TCAS interrogations. TCAS interrogations are still relied on to track threat aircraft, thus TCAS should not take any action on the receipt of a DF=18 message.

However, all Mode S signals that are received by the TCAS interrogator within the window of an expected reply will need to be decoded to some extent before they can be rejected. This, and the probability that a DF=18 squitter will garble a wanted signal, will mean that EC devices will degrade TCAS's ability by interfering with the reception of wanted signals. If EC signals in the environment remain low in comparison to other sources of FRUIT, the interference will be minimal.

2.7 Effect on TCAS of EC device Single point failure

As has been discussed above, it is anticipated that the effects of correctly operating EC devices will be minimal on TCAS equipments. However, this study was also required to determine the effects of a worst-case single point of failure for an EC device on a TCAS system. To do this the following possibilities were considered:

1. False information being broadcast by EC device;
2. Continuous Wave (CW) signal being broadcast;
3. Incorrect rate of squitter broadcast.

The effect of false information being broadcast by an EC device will depend largely on what format the broadcast appears to be. TCAS only recognises three types of signals: Mode C replies; Mode S acquisition squitters (DF=11) and Mode S DF=0 replies. It is considered highly unlikely that the EC device would produce a signal that could be interpreted as a Mode C reply, but it is conceivable that the wrong format could be broadcast. A DF=0 signal would have to be received at the same time as a wanted signal and then be decoded such that the information was considered to be relevant – all the fields were correctly encoded and the aircraft address identical to the address of the wanted reply. This is considered to be extremely unlikely as it is more likely that the EC device broadcast would be rejected as having errors. A false Acquisition Squitter is more likely to be processed and accepted by a TCAS device. As these squitters can be received at any time with an unknown aircraft address encoded, it is possible that this could result in credible information being falsely decoded and acted upon. As a worst case this would mean that the EC device would be considered to be a transponding aircraft and interrogated as such. Since the EC device would not respond, the TCAS system would not track it and so the overall effect of the fault would be an increase in TCAS processing, but at levels consistent with a single extra aircraft.

It is not known exactly how a TCAS equipment would react to a CW broadcast. It is assumed that the effect would be an increase in the noise floor of the environment. Wanted signals that are sufficiently above this noise floor would continue to be decoded correctly whilst those beneath or equal to the noise levels could be expected to be drowned out. As transponders have significantly higher output powers when compared to the EC devices proposed (250W compared to a maximum of 70W) the EC device would need to be between the wanted aircraft and the TCAS device in order to jam the signal. At the ranges TCAS is designed to operate at this would mean that the EC device would be close to, or within, the aircrafts' separation distance.

A CW broadcast will also affect the ability of a transponder to be able to recognise and respond to interrogations – including TCAS. A study prepared for OFCOM [11] determined that transponders could fall below the 90% Successful Message Rate when subjected to CW noise ~9dB below a wanted signal. It is expected that the power of the TCAS transmitter coupled with the antenna gain of the system would ensure that TCAS interrogations are significantly above this threshold for any CW broadcast by an EC device. Unless the EC device is within a similar range as the TCAS interrogator to the target transponder.

A failure considered more likely than the false information broadcast is where the rate of Extended Squitters is much higher than that allowed. As each received Mode S broadcast would undergo some processing before it was rejected, this could have a significant effect on the TCAS equipment's ability to receive wanted signals. Thus a high rate of Extended Squitters could have a greater detrimental effect than an equivalent power CW broadcast.

In view of the above, it is considered that the worst credible single fault that an EC device could have would be for the rate of Extended Squitters to be well above that specified. This would not cause the TCAS system to change its behaviour, but would mean that it is more likely that a wanted signal would be garbled or lost.

3 Scenarios Analysed

3.1 Modelling Runs

Five modelling runs were performed:

- Run 1 – A Baseline run with no GA EC devices. GA aircraft are limited to those currently equipped with transponders;
- Run 2 – This run is identical to the Baseline run with the addition of EC devices on GA aircraft that are not currently equipped with transponders. The GA EC devices operate with a transmit power of 10W;
- Run 3 – Identical to Run 2 but with the EC devices operating with a transmit power of 20W;
- Run 4 – Identical to Run 2 but with the EC devices operating with a transmit power of 40W;
- Run 5 – Identical to Run 2 but with the EC devices operating with a transmit power of 70W;

SIEM modelling runs are built from a number of modelling “components”, each of which defines a category of platforms. These can comprise interrogators and/or transponders.

Each modelling run comprised the following background components:

- Permanent interrogators (UK and non-UK);
- Midweek Test and Development interrogators;
- Midweek Military interrogators;
- Civil Commercial aircraft;
- GA (transponder-fitted) aircraft;
- Military aircraft.

For Runs 2 to 5, an additional component of GA aircraft with EC devices derived from the Class G modelling undertaken for the CAA [12]. Details of all these components are presented in the remainder of this section.

3.1.1 Permanent Background Interrogators

This component represents all the ground interrogators that are likely to be operating, regardless of time of day or aircraft scenario composition. The component is divided into UK and non-UK interrogators and is intended to represent all permanently approved interrogators that are likely to be radiating. The component also includes military interrogators, both fixed (e.g. those at MOD airfields) and a representative number of mobile platforms (e.g. E3D Sentry surveillance aircraft).

UK information is based upon licensed interrogator information as provided by the NISC.

The non-UK information covers ground-based interrogators in Ireland and western continental Europe. The information has been derived over a number of years from a variety of sources. The component is regularly used in NISC modelling tasks. However, it is accepted that the component does not provide an exhaustive list of non-UK interrogators. Furthermore, their modelled operational characteristics may not be current. However, as SIEM modelling is not intended to provide absolute metrics but relative differences in spectrum performance, this component is considered sufficient. Whilst it is important to keep the baseline scenarios as accurate as possible, it is the difference between the baseline and the addition of the new system that is the useful result.

The following civil UK interrogators were modelled as Mode S Enhanced Surveillance (EHS), operating a standard Mode S Mode Interlace Pattern (MIP) of SAs, SCs (*i.e*. Mode S All Call with Intermode A short P4 followed by a Mode S All Call with Intermode C short P4) followed by a RollCall period:

- Allans Hill;
- Bovingdon;
- Burrington Combined;
- Burrington;
- Cardiff;
- Claxby;
- Debden;
- Gatwick CCF;
- Glasgow;
- Guernsey Airport;
- Heathrow South;
- Lowther Hill;
- Manston Airport;
- Oxford Airport;
- Pease Pottage;
- Perwinnes Hill;
- RRH Benbecula;
- RRH Portreath;
- Southend Airport;
- Stornoway 1;
- Stornoway 2;
- Sumburgh/Fitful Head;
- Tiree.

The following UK interrogators were modelled as Mode S Enhanced Surveillance (EHS), operating a standard Mode S MIP of SA, SC½ (i.e. Mode S All Call with Intermode A short P4 followed by a Mode S All Call with Intermode C short P4 with a 50% chance of reply) followed by a Mode S Roll Call period:

- Farnborough RRF;
- Manchester.

The following UK interrogators were modelled as Mode S Elementary Surveillance (ELS), operating a standard Mode S MIP of SA, SC followed by a Roll Call period:

- Belfast City;
- Belfast International;
- Belfast;
- Clee Hill Combined;
- Cromer;
- Doncaster;
- Gatwick RSS;
- Great Dunfell;
- Inverness;
- Newquay;
- St Annes RSS;
- Stansted;
- Trimingham;
- Warton.

3.1.2 Midweek Test and Development Interrogators

This component reflects the additional interrogator activity that would occur during weekday working hours. In general, the additional activity is due to the use of non-operational interrogators, either for technical research or product development.

3.1.3 Midweek Military Interrogators

This component represents the increased level of traffic that results from standard military exercises held during the week. The component comprises 40 Rapier Field Standard C (FSC) and 36 High Velocity Missile (HVM) ground interrogators, plus 16 additional aircraft interrogators and 3 naval interrogators.

3.1.4 Civil Commercial Aircraft Component

This component was based upon the standard civil commercial aircraft modelling component, which had been derived from NATS UK radar recordings from 12th June 2006. To account for the expected traffic growth at the time of GA EC introduction, the set of civil commercial aircraft was increased by 25%. This was performed by randomly selecting 25% of the platforms and extrapolating their horizontal position by between 5 and 10NM along the aircraft heading to create a new platform location. The aircraft height was varied by between ±3,000ft, limiting base height to 1,000ft.

The total number of civil commercial aircraft after the 25% increase was 643.

All civil commercial aircraft were assumed to be equipped with TCAS II and a Mode S EHS capable transponder operating with a 6.2Hz Extended Squitter rate.

A map showing the Civil Commercial Aircraft Component is shown Figure 3-1.

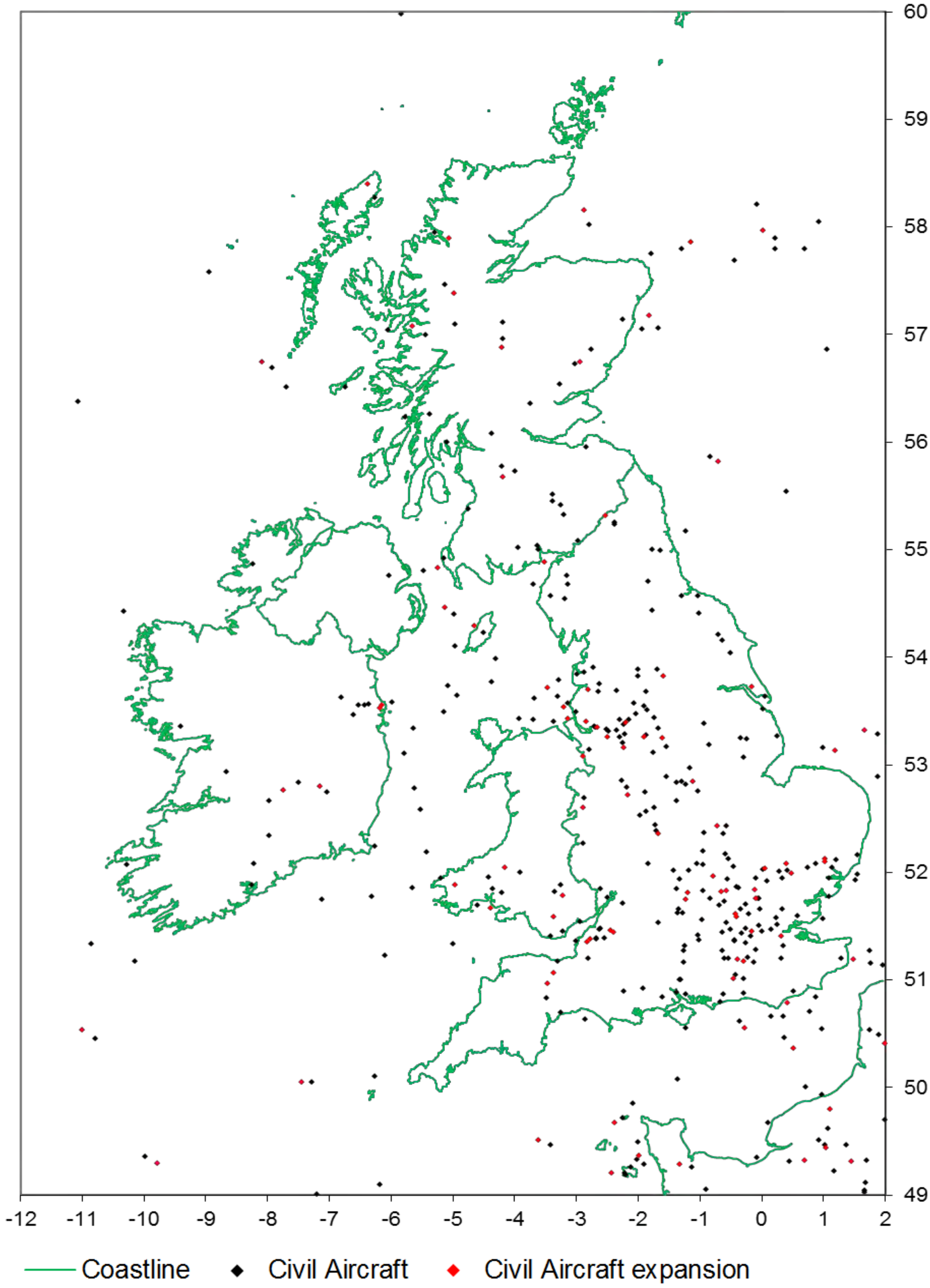

Figure 3-1 Civil Commercial Aircraft

3.1.5 Transponding General Aviation Component

This component contains a typical distribution of GA aircraft and is based upon NATS radar data. The component has been used for a number of years in SIEM modelling tasks for the NISC. All the aircraft are transponder equipped.

The total number of GA aircraft in the component is 170.

The equipage proportions for GA aircraft in this component are shown in Table 3-1. The Extended Squitter rate on GA aircraft with ADS-B capability was assumed to be 4.23Hz (*i.e*. the same as that of the GA EC devices).

3.1.6 Military Aircraft Component

The typical military aircraft component was used, which has been used for a number of years in SIEM modelling tasks for the NISC.

The total number of military aircraft is 183.

The equipage proportions on these military platforms are shown Table 3-1.

Capability	Civil Commercial	GA	Military
Mode A/C Only	0%	10%	0%
Mode S ELS	0%	80%	80%
Mode S EHS	0%	0%	0%
Mode S EHS + TCAS II	0%	0%	15%
Mode S EHS + TCAS II + Extended Squitter (ES)	100% (6.2Hz ES)	10% (4.23Hz ES)	5% (4.23Hz ES)

Table 3-1: Transponding Aircraft Equipments

3.1.7 GA aircraft with EC devices Component

This component was added to Runs 2 to 5. It contained a distribution of 828 GA aircraft without transponders that were fitted with EC devices. The distribution of aircraft was based on the probability distribution from the Class G modelling study [12].

The GA EC devices were modelled as broadcasting Extended Squitter at a rate of 4.23Hz. The transmit power of the EC devices was set to between 10W and 70W depending on the modelling run.

'Squitter box' devices, *i.e*. non-transponding equipment that broadcasts Extended Squitter information, the squitter should be in the DF=18 format which alerts the recipient that the transmitter will not reply to interrogations. This would be the case for the GA EC equipment, which is not expected to respond to interrogations.

SIEM2 appears to only permit modelling of Extended Squitters using DF=17, which is the format intended for use by transponder devices. Consequently, the GA EC devices were modelled as transmitting DF=17 format Extended Squitter, even though they were modelled as having no transponder capability (*i.e*. not able to respond to any interrogations).

This difference in Extended Squitter format is considered to be academic from the perspective of this modelling task as DF=17 and DF=18 are identical in terms of message length/time. Furthermore, the only surveillance system that should be accepting Extended Squitters as part of its surveillance process is the North Sea Wide Area Multilateration (WAM) system, and this system is not modelled as interrogating in response to receiving Extended Squitters.

In summary, the GA EC devices have been modelled as broadcasting an incorrect format of Extended Squitters, but it is not considered that this will impact the modelling results as no equipment within the Area of Interest (*i.e*. the LTMA) should be reacting to receiving Extended Squitters. In particular, no TCAS equipment is modelled as using 'Hybrid Surveillance' (as explained in Section 2).

QinetiQ will be contacting the stakeholders of SIEM2, with regards the possibility of modelling DF=18 in future modelling tasks.

Whilst the aircraft in the civil commercial, military and transponding GA components described in Sections 3.1.4 to 3.1.6 are spread throughout the UK Flight Information Region (FIR) and beyond, the GA EC device deployment is limited to the South East of England. This is the area covered during the earlier work on Class G airspace [12] and so is the extent of the probability distribution data as used for determining the GA EC aircraft distribution. It is not considered that the geographical limitation of this distribution will impact the modelling results within the Area of Interest (*i.e*. the LTMA). This is because the GA EC device transmit powers coupled with the low altitude of these aircraft (less than 5000ft) means that they will not be detected over long distances.

The distribution of the GA EC device aircraft in the South East of England is shown in Figure 3-2 below. The GA EC devices are shown in conjunction with the LTMA boundaries and the six civil commercial TCAS aircraft that were chosen as test aircraft to measure the Probability of Detection and Round Trip Probability (see 3.1.8). Figure 3-2 also shows the horizontal boundaries of the LTMA and the box that has been designated by the CAA [13] as an area of significant RA encounters between GA and civil commercial aircraft.

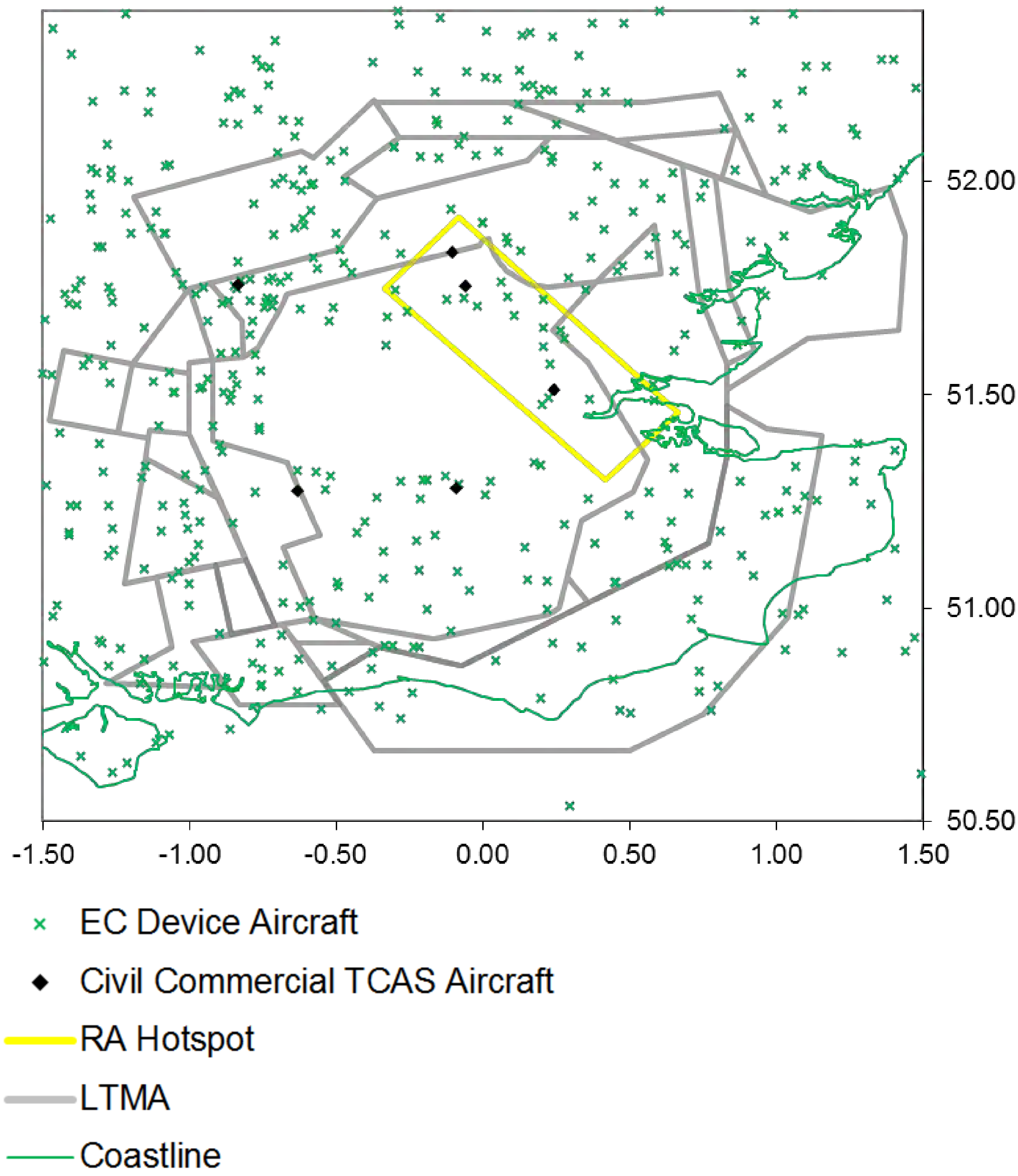

Figure 3-2 GA EC Device Aircraft and Six Test TCAS Aircraft

3.1.8 Test TCAS aircraft

Six test aircraft equipped with TCAS were selected to be within the horizontal boundaries of the LTMA. Three were within the Brookmans Park (BPK) to Gravesend TCAS RA hot spot (shown in Figure 3-2). The remaining three were chosen from TCAS aircraft outside this area, but within the LTMA horizontal boundaries and close to clusters of GA aircraft with EC device equipment. As can be seen from Table 3-1 'Test6' is within the densest cluster of GA EC device equipped aircraft near Halton airfield.

It is noted that there is no increase in number of GA EC device aircraft visible for this set of TCAS aircraft when the EC device power is increased from 10W to 20W. This is because this increase in power is not sufficient to bring further EC device aircraft into coverage of the test aircraft.

Aircraft	Lat	Lon	Details
Test1	51º50'N	000º06'W	In RA Hotspot Box
Test2	51º45'N	000º03'W	In RA Hotspot Box
Test3	51º30'N	000º14'E	In RA Hotspot Box
Test4	51º16'N	000º05'W	North of Redhill
Test5	51º16'N	000º37'W	Near Farnborough
Test6	51º45'N	000º50'W	Near Halton airfield

Table 3-2: Test Aircraft Locations

Aircraft	Scenario				
	Baseline	10W	20W	40W	70W
Test1	0	15	24	61	109
Test2	0	15	25	48	91
Test3	0	8	16	37	70
Test4	0	11	20	37	70
Test5	0	11	24	63	107
Test6	0	28	48	87	127

Table 3-3: Numbers of GA EC device Aircraft visible by Test Aircraft

4 Main Results

4.1 Introduction

The mutual interference effects were measured by considering the six test TCAS aircraft stated in Section 3.1.8.

The following results are presented:

- Round Trip Probability (RTP) for Mode S Roll Call interrogations;
- Probability of Plot Detection (PD) based on Mode S Roll Call replies;
- Mean FRUIT rates received in main-beam.

It is noted that for the TCAS aircraft modelled, the Code Validation results are identical to the Probability of Detection as the same number of plots are required to declare a plot as to determine a code as valid.

4.2 Round Trip Probability

The Round Trip Probability (RTP) is the probability that a single interrogation will result in a decoded reply from a transponder. This combines the likelihood that the interrogation will be received, decoded and replied to by the transponder with the possibility that the transponder reply will be received and correctly decoded by the interrogator. The RTP as such is not affected by the interlace pattern used by the interrogator or by the number of replies required to prove a plot exists through correlation.

In the calculation of this metric, it was observed that some aircraft detected by a TCAS test aircraft in the Baseline scenario dropped out of coverage in the 70W EC device scenario. This had a disproportionately large effect on the average result and so it was decided to remove these aircraft from all of the modelling run results for that TCAS test aircraft. This resulted in a consistent aircraft sample for each TCAS test aircraft across all modelling runs.

The results are shown in Table 4-1.

Aircraft	Scenario				
	Baseline	10W	20W	40W	70W
Test1	73.80	73.78	73.67	73.56	73.37
Test2	75.46	75.36	75.30	75.18	74.81
Test3	74.69	74.60	74.54	74.45	74.34
Test4	72.96	72.87	72.78	72.69	72.56
Test5	69.70	69.65	69.59	69.43	69.19
Test6	70.71	70.51	70.34	70.05	69.79

Table 4-1: Average TCAS Round Trip Probability per Test Aircraft

4.3 Probability of Detection

Probability of Detection (PD) is the probability that a target will be detected by a surveillance device within one scan period or equivalent. As such this metric will conflate the probabilities that enough interrogations will be received and replied to by a transponder for the interrogator to decode and correlate proving a plot.

Once again, this metric was calculated for only the aircraft that were within coverage of the chosen test TCAS interrogator for all five scenarios. This resulted in a consistent aircraft sample for each TCAS test aircraft across all modelling runs and a measurement that was not affected by aircraft at the edge of coverage dropping out. The results for PD are shown in Table 4-2.

Aircraft	Scenario				
	Baseline	10W	20W	40W	70W
Test1	91.80	91.79	91.98	92.06	93.79
Test2	87.90	87.88	87.87	87.84	87.74
Test3	78.17	78.13	78.11	78.06	78.01
Test4	77.78	77.73	77.68	77.63	77.55
Test5	62.09	62.06	62.02	61.93	61.78
Test6	90.65	90.57	90.51	90.39	90.30

Table 4-2: Average TCAS Probability of Detection per Test Aircraft

4.4 FRUIT Levels

FRUIT received at an interrogator are all the transponder broadcasts and replies that are detected by the interrogator but are unwanted. This will include replies to other interrogators that are received by chance, squitters that cannot be used by the interrogator or false replies caused by the transponder mistakenly replying incorrectly to an interrogation. FRUIT causes interference at the receiver and so any increase in FRUIT should be avoided if possible. Interrogators have differing abilities in being able to pull wanted signals out of the interference of FRUIT which will depend on the wanted reply received, the FRUIT type and the capability of the receiver system.

The FRUIT levels received at the TCAS Test aircraft are given in Table A-1 to Table A-6. A graph of the Extended Squitter FRUIT[3] levels at each of the test aircraft is shown in Figure 4-1.

[3] For the purposes of this study, all Extended Squitter broadcasts are being treated as FRUIT for the TCAS aircraft.

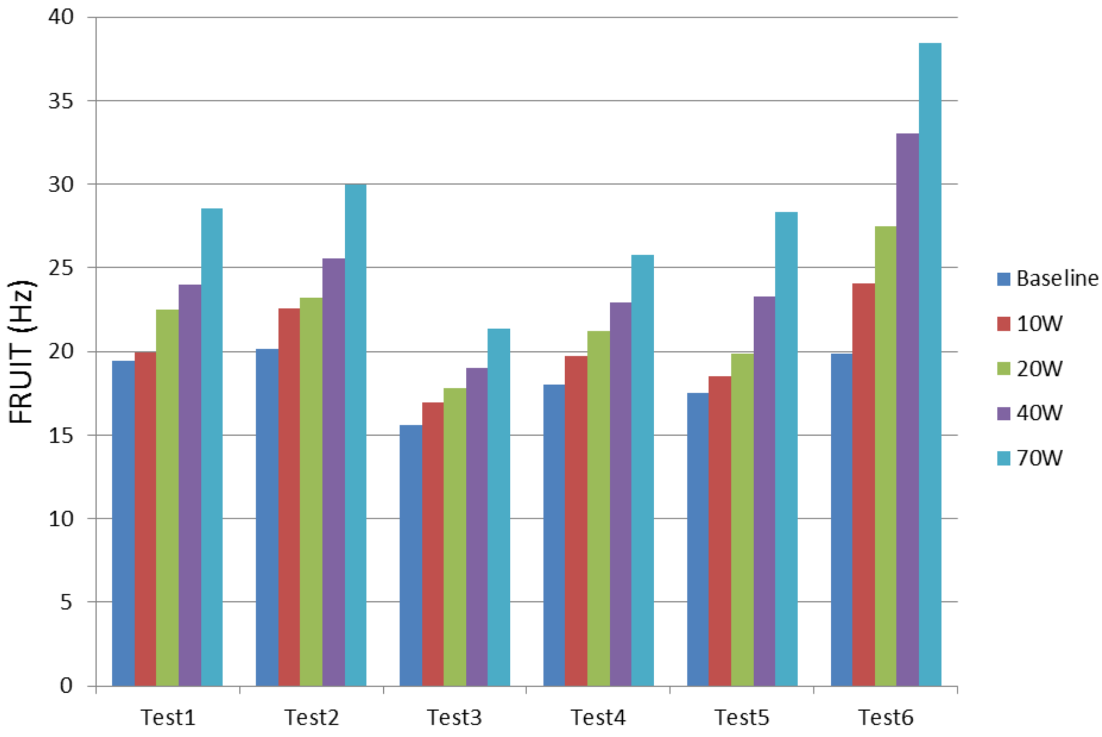

Figure 4-1 Extended Squitter 'FRUIT' levels

5 Comments

5.1 Round Trip Probability

The average Round Trip Probability (RTP) results show a uniform slight decrease as EC devices are introduced on GA aircraft with increasing power. The greatest decrease is for the Test6 aircraft which has a drop in RTP of 0.92 ppts between the Baseline and 70W EC device scenario. This is expected as Test6 aircraft has the greatest number of EC devices within coverage and so it is not surprising to be the heaviest affected.

It is noted that the results are for all aircraft under coverage of the test aircraft and they are treated equally for averaging. This will mean that aircraft that are not considered a TCAS threat at the edge of coverage will be included.

5.2 Probability of Detection

The Probability of Detection (PD) of aircraft within the coverage of the six TCAS Test aircraft mostly decrease slightly as the EC devices are introduced on GA aircraft with increasing power. The exception to this is the aircraft 'Test1' for which the PD unexpectedly increases for the 20W and 70W scenarios. This is discussed in Section 5.4 below.

The greatest decrease in PD is 0.36ppts for the Test6 aircraft between the Baseline and 70W scenarios.

5.3 FRUIT

As expected, the levels of DF=17 FRUIT increase in proportion to the power of the GA EC devices introduced into the scenarios. In the real environment, the increase in FRUIT would be DF=18 messages with the DF=17 remaining stable. The largest increase is a 94% increase in DF=17 levels between Baseline and 70W scenarios for the Test6 TCAS aircraft. This increase is a significant proportion of the overall FRUIT level received by the TCAS equipment.

The majority of other FRUIT levels decrease insignificantly. The exception to this insignificant decrease in FRUIT is the levels of unwanted UF=0/DF=0. These decrease by a small, but significant amount, 2.9% for Test6 TCAS aircraft between Baseline and 70W scenarios. It is not known what is causing this as the UF=0/DF=0 FRUIT is caused by TCAS to TCAS interactions and these equipments interrogation rates should not be affected by the presence of EC devices. It is possible that this effect is linked to the changes in TCAS rates of interrogation commented on in Section 5.4.

5.4 Discussion on PD issues

The increase in PD for a single TCAS test aircraft for the 20W and 70W scenarios is unexpected and goes against the uniform decrease in RTP described in Section 5.1 above.

After some examination of the results and parameters produced by SIEM2 the cause of the increase was due to an increase in the rate of interrogation for a small number of aircraft within the coverage of the 'Test1' aircraft. This increase in interrogation rate overshadowed the decrease in RTP and increased the PD for these aircraft significantly.

It is also possible that this change in interrogation rate has the same root as the unexpected slight decrease in UF=0/DF=0 FRUIT noted in Section 5.3 above.

It is not known why the rate of interrogations should increase when there is an increase in Extended Squitters being received. Even if the ES received are all being modelled as DF=17. It is possible that SIEM2 is correctly modelling a second order effect where the increase in FRUIT garbles Mode A/C interrogations which could result in a relaxation of TCAS Interference Limiting although this is considered unlikely.

This issue does not affect the RTP results and so it is suggested that the emphasis of the comparison should be on the RTP results. It is not expected that this issue affecting aircraft will be borne out in practice, and it is recommended that details are passed on to the SIEM2 developers for their consideration.

6 Summary

This study examined the effects of equipping a large number of GA aircraft without transponders with EC devices in South East England. The influence these devices had on six TCAS equipped aircraft was examined. The TCAS aircraft were selected in the areas expected to be most affected by the introduction of EC device. Consequently it can be anticipated that the results will be for a worse-case scenario of introducing EC devices to the UK airspace.

The following points are noted in this study:

- In the theoretical analysis of the worst credible single failure of an EC device, it was determined that an Extended Squitter broadcast rate incorrectly at a very high rate would have the worst effect on TCAS equipments. This would cause the single EC device to garble wanted signals in the same way that large numbers of EC devices would.
- In the worst observed case, for a TCAS equipped aircraft located in a cluster of EC device equipped GA aircraft, the Extended Squitter FRUIT rate almost doubled between the Baseline scenario with no EC devices and the scenario in which 70W EC devices had been introduced;
- As a consequence of introducing 70W EC devices the maximum drop in average Round Trip Probability was just under 1% for a single TCAS equipment;
- Introducing 70W EC devices caused a maximum drop of below 0.4% in the average Probability of Detection at one of the selected TCAS equipments;
- The results for Code Validation are identical to that for PD as the decoding and correlation parameters are identical.

These effects should be considered against the benefit of having non-transponding aircraft under surveillance.

It is noted that TCAS employs Interference Limiting strategies to ensure that the availability of the TCAS aircraft's transponder to reply to an interrogation will not drop by more than 2%. As this has been considered an acceptable level of degradation for an airborne safety system, it is possible that the figures described above could be considered to demonstrate that introducing EC devices should not cause a drop in Probability of Detection of a TCAS equipment by 2%.

7 References

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[2] "*Low Power ADS-B Transceiver (LPAT) RF Environment Modelling Study - Phase 2*", QINETIQ/14/01558, QinetiQ, A Peaty, 10th June 2014.

[3] "*DO-260B Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information Services - Broadcast (TIS-B)* ", DO-260B, RTCA, 12/2/2009.

[4] "*ED-102A with Corrigendum 1 - Electronic Copy - MOPS for 1090 MHz Extended Squitter Automatic Dependent Surveillance - Broadcast (ADS-B) & Traffic Information Services - Broadcast (TIS-B).*" ED-102A with Corrigendum 1, EUROCAE, Jan 2012.

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8 List of Abbreviations

ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance - Broadcast
ATC	Air Traffic Control
ATM	Air Traffic Management
BPK	Brookmans Park
CAA	Civil Aviation Authority
CW	Continuous Wave
DF	Downlink Format
EC	Electronic Conspicuity
EHS	Mode S Enhanced Surveillance
ELS	Mode S Elementary Surveillance
ES	Extended Squitter
EU	European Union
FIR	Flight Information Region
FRUIT	False Replies Unsynchronised In Time
FSC	Field Standard C Rapier system
GA	General Aviation
HVM	High Velocity Missile
ICAO	International Civil Aviation Organization
IFF	Identification Friend or Foe
LTMA	London terminal control area
MIP	Mode Interlace Pattern
MOPS	Minimum Operational Performance Standards
NISC	National IFF/SSR Committee
NM	Nautical Miles
PD	Probability of Detection
ppt(s)	Percentage point(s)
RA	Resolution Advisory
RAC	Resolution Advisory Complement
RF	Radio Frequency
RTP	Round Trip Probability
SARPS	Standards and Recommended Practices
SIEM	SSR IFF Environment Model
SSR	Secondary Surveillance Radar
TCAS	Traffic alert and Collision Avoidance System
UF	Uplink Format
WAM	Wide Area Multilateration system

A Detailed Results

A.1 FRUIT Rates (Hz)

Mean FRUIT rates received by the Main Beam for the indicated Test TCAS aircraft.

FRUIT	Scenario				
	Baseline	10W	20W	40W	70W
DF17	19.43	19.94	22.48	24.00	28.57
Mode1	6.18	6.18	6.18	6.18	6.18
Mode2	3.73	3.73	3.73	3.73	3.73
Mode3A	319.79	319.77	319.76	319.74	319.73
ModeC	276.31	276.30	276.29	276.28	276.27
ModeSAllCall	17.23	17.23	17.23	17.23	17.23
UF0DF0	9.02	9.02	9.02	8.94	8.76
UF20DF20	18.47	18.47	18.47	18.47	18.47
UF4DF4	22.81	22.80	22.80	22.80	22.80

Table A-1: Test1 Aircraft FRUIT Results

FRUIT	Scenario				
	Baseline	10W	20W	40W	70W
DF17	20.18	22.55	23.22	25.59	29.99
Mode1	3.50	3.50	3.50	3.50	3.50
Mode2	1.06	1.06	1.06	1.06	1.06
Mode3A	314.38	314.36	314.34	314.32	314.31
ModeC	271.00	270.98	270.97	270.95	270.94
ModeSAllCall	17.82	17.82	17.82	17.82	17.82
UF0DF0	9.05	9.05	9.05	9.01	8.87
UF20DF20	18.75	18.75	18.75	18.75	18.74
UF4DF4	24.41	24.40	24.40	24.40	24.40

Table A-2: Test2 Aircraft FRUIT Results

FRUIT	Scenario				
	Baseline	10W	20W	40W	70W
DF17	15.62	16.98	17.82	19.01	21.38
Mode1	6.49	6.49	6.49	6.49	6.49
Mode2	2.84	2.84	2.84	2.84	2.84
Mode3A	279.08	279.07	279.06	279.04	279.03
ModeC	237.92	237.90	237.90	237.88	237.88
ModeSAllCall	16.13	16.13	16.13	16.13	16.13
UF0DF0	7.89	7.89	7.89	7.87	7.73
UF20DF20	14.57	14.57	14.57	14.57	14.57
UF4DF4	23.63	23.62	23.62	23.62	23.62

Table A-3: Test3 Aircraft FRUIT Results

FRUIT	Scenario				
	Baseline	10W	20W	40W	70W
DF17	18.03	19.72	21.24	22.93	25.81
Mode1	12.65	12.64	12.64	12.64	12.64
Mode2	8.67	8.66	8.66	8.66	8.66
Mode3A	305.78	305.76	305.75	305.73	305.72
ModeC	281.77	281.75	281.74	281.73	281.72
ModeSAllCall	18.11	18.11	18.11	18.11	18.11
UF0DF0	8.31	8.31	8.31	8.29	8.18
UF20DF20	17.30	17.30	17.30	17.30	17.30
UF4DF4	27.47	27.46	27.46	27.46	27.46

Table A-4: Test4 Aircraft FRUIT Results

FRUIT	Scenario				
	Baseline	10W	20W	40W	70W
DF17	17.53	18.54	19.90	23.28	28.36
Mode1	16.49	16.49	16.48	16.48	16.48
Mode2	14.76	14.75	14.75	14.75	14.75
Mode3A	308.42	308.39	308.38	308.37	308.35
Mode4	0.24	0.24	0.24	0.24	0.24
ModeC	305.64	305.62	305.61	305.59	305.58
ModeSAllCall	17.62	17.62	17.62	17.62	17.62
UF0DF0	8.03	8.03	8.03	8.02	7.95
UF20DF20	16.81	16.81	16.81	16.81	16.81
UF4DF4	26.57	26.57	26.57	26.56	26.56

Note: Test5 aircraft receives some Mode 4 FRUIT

Table A-5: Test5 Aircraft FRUIT Results

FRUIT	Scenario				
	Baseline	10W	20W	40W	70W
DF17	19.85	24.08	27.47	33.05	38.46
Mode1	26.52	26.52	26.52	26.52	26.52
Mode2	23.44	23.44	23.44	23.44	23.44
Mode3A	400.88	400.86	400.85	400.86	400.86
ModeC	398.31	398.30	398.29	398.30	398.30
ModeSAllCall	19.69	19.69	19.69	19.69	19.69
UF0DF0	9.97	9.97	9.97	9.81	9.68
UF20DF20	20.32	20.32	20.32	20.32	20.32
UF4DF4	27.78	27.77	27.77	27.77	27.77

Table A-6: Test6 Aircraft FRUIT Results

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Abstract

The Electronic Conspicuity Working Group has identified a potential requirement for an affordable Automatic Dependent Surveillance – Broadcast (ADS-B) Out capable device for General Aviation (GA) users, which will employ 1090 MHz Extended Squitter with the aim of improving GA safety and to help mitigate the risk posed by infringements of controlled airspace. However, there is European Union (EU) legislation in place to ensure that the Interrogator Friend or Foe (IFF) / Secondary Surveillance Radar (SSR) spectrum is protected from interference that could harm the performance of current SSR systems.

There has already been work undertaken that shows that the introduction of significant numbers of ADS-B Out equipped GA aircraft would have minimal effect on the ability of ground surveillance systems to detect existing transponder-equipped aircraft. However, to date, there has not been a study to analyse the effect that ADS-B Out equipped GA aircraft could have on Traffic alert and Collision Avoidance System (TCAS) equipped aircraft.

This study analyses the effects that significant numbers of ADS-B Out equipped GA aircraft have on TCAS II equipped aircraft within the London terminal control area (known as the LTMA). The study concludes that these devices would have a minimal effect on the ability of the TCAS II to operate.

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