(*Above*) **A PowerFLARM unit – this technology was originally developed for glider pilots, and has been in use for over a decade.** *(Photo: www.flarm.com)*

ELECTRONIC CONSPICUITY

Ian Fraser explains the theory behind and practical application of 'EC', an umbrella term for technologies which allow you to 'see and be seen' by other aircraft

Doubtless many LAA members have recently noticed the term electronic conspicuity or EC, and the slogan 'see and be seen' mentioned in a number of adverts and news items. Perhaps you wondered, "What is it?", "Should I buy it?" and, if so, "What should I buy?" Well, the answers to those questions very much depend on what you expect EC to do for you, so this article looks at the subject from the viewpoint of a potential customer.

NEW ADVANCES

In practical terms, EC is an electronic beacon that's carried on your aircraft, which transmits your GPS-derived identity, position, height, direction and speed on a special radio frequency. That enables anyone in range, with a compatible receiver, to be alerted to your presence and, depending on their equipment, generate a proximity warning, a risk of collision warning or a display of your position. To see similarly-equipped aircraft, you also need to have a receiver.

From a collision avoidance point of view, this is a move in the right direction, but it'll only become truly effective when enough of us fit compatible EC transmitters and receivers which can 'see' one another, and we're a long way from that at the moment…

DIFFERENT STANDARDS

Currently, the certified EC standard is ADS-B (Automatic Dependent Surveillance – Broadcast) which, as its name implies, automatically broadcasts GPS-derived data that can be received by ground stations (ATC) and also suitably equipped aircraft.

At the non-certified end of the market, we have FLARM (FLight alARM), which was originally developed for glider pilots, who regularly fly in close proximity to each other.

FLARM transmits and receives position data in its own unique standard, and proximity warnings can only be received by other aircraft carrying FLARM equipment.

Finally, we have PilotAware, which also transmits its own standard (P3i) and can receive that, Mode S, Mode A/C and ADS-B.

The US is using a system known as UAT (Universal Access Transceiver), which transmits position data to a ground station that relays all know traffic information plus live weather, notams, etc, back to your aircraft. Although some 'dual-band' transponders available in UK are equipped to do this, the UAT traffic service isn't available in Europe.

THE CAA'S VIEW

The CAA is trying to encourage all pilots to equip their aircraft with EC beacons. As described, several companies have products available today which offer varying functional capability but with non-compatible standards.

Recently, as part of a safety initiative, the CAA published *CAP1391*, which defines

EC SYSTEM COMPATIBILITY

RECEIVERS / TRANSMITTERS	Mode S	ADS-B	*CAP1391*	FLARM	P3i
ADS-B In					
CAP1391 (eg uAvionix)					
FLARM	option	option	option		
PilotAware P3i				option	
ATC	?	?	?		
Aircraft Tracking apps. (internet)					

KEY: Red is incompatible, Green is compatible and a question mark means that I'm uncertain…

another 'low-cost' standard for an EC beacon, and with it the regulator announced that ADS-B, and its derivatives transmitting on 1090mHz, are its preferred standard in the UK.

The *CAP1391* spec is for a "portable, low-power" device using the same frequency and format as the existing, more powerful certified standard, ADS-B. The CAA suggests that such a beacon should cost about £250.

Unlike the existing, low-cost EC beacon standards, FLARM and P3i, the new one can be 'seen' by ADS-B 'In' equipment but, disappointingly, it seems to be incompatible with current ATC kit and can't currently be operated at the same time as a Mode S transponder. The CAA is still investigating these issues and conducting trials using a portable device, manufactured to the *CAP 1391* standard by an American company, uAvionix.

There seems to be a belief among its champions that coverage from a cockpit-mounted portable device is isotropic – ie that it can be seen from all round your aircraft. That's almost certainly a long way from reality and the actual coverage is one of the key issues which must be addressed if electronic conspicuity beacons really are to work.

YOU PAYS YER MONEY…

The CAA's target of £250 for a beacon is supposed to be an incentive to get as much take up as possible but, unfortunately, it's only part of the story. What you might get for £250 is quite basic and will provide only partial coverage around your aircraft. Ergo, full coverage will probably cost much more.

I'm not sure the CAA has fully understood the market or the requirements from a pilot/owner's point of view. In the regulator's own words, it's about 'seeing and being seen', but its solution only really considers the latter, and not very comprehensively, at that. The cost of 'seeing' is additional and I certainly wouldn't consider putting any EC in my aeroplane without also being able to 'see' similarly equipped aircraft, and also holding the belief that most others will be carrying an effective beacon during my flying lifetime.

In my 1,800 hours of flying I've experienced several close calls from directions which I couldn't have seen – below and behind. Although basic EC equipment may work as an aid to spotting aircraft out front and to the side, its potential to see all around must be explored. I've looked at this from a point of view of equipping my Van's RV-6 with effective EC and am sharing my conclusions here, for the benefit of my fellow flyers.

WHAT DO I BUY?

The key questions which need to be addressed before buying any EC system are:

- What standard should I adopt?
- How well does the equipment work and what do I have to do to ensure that it's effective?

The key issue for the overall effectiveness of EC is compatibility – the more of us that can see one another, the better!

The table shown above identifies each of the standards transmitted and identifies which systems, according to their respective publicity, can receive them.

For example, the table shows that although a PilotAware system can receive (ie see) most of the standards, none of the others can see its P3i transmissions. An ADS-B In receiver can see *CAP1391* but not Mode S, FLARM or P3i, and so on. The transmissions that can be seen by most devices are ADS-B or *CAP1391*, so either would be my preferred beacon standard.

Although many systems claim to see multiple standards, one must be careful, as the receivers don't always process and display all of them in the same way. Some receivers display the full position data for aircraft transmitting one standard, while only detecting and reporting the presence of a signal (proximity) for others. Although a general proximity warning might be useful in ›

The PilotAware system can receive Mode S, Mode A/C, ADS-B and (with additional equipment) FLARM, and also has its own standard, P3i, which it can both transmit and receive. *(Photo: www.pilotaware.com)*

transit, it could be a nightmare in a busy circuit. My preference is for a receiver which gives full position data on as many of the standards as is practicable, including the most popular ones, namely ADS-B / *CAP1391* and FLARM.

Another key issue for receivers is how alerts and data are presented to the pilot. Some present it on a tablet or smart phone, others a permanent compass or radar-style display, and some give an audio alert through your headset.

My principle issue is with the cockpit clutter which results from this myriad of 'portable' devices – I'd prefer an installed solution.

COVERAGE AND EFFECTIVENESS

Having decided on the standard to adopt, I see little point in installing a beacon which only provides limited coverage, nor a receiver that solely identifies that which can already be seen visually. To be effective, a system must see and be seen by the majority of threats at an adequate range to do something about it.

Based on a one-minute warning, the Diagrams 1 and 2 indicate the sort of range and coverage required to achieve a one-minute warning for my RV-6.

> "My preference is for a receiver which gives full position data on as many of the standards as practicable, including the most popular ones, namely ADS-B / *CAP1391* and FLARM"

For conspicuity to work between two aircraft, their beacon transmission must be of sufficient strength over the whole spatial coverage required (range and azimuth), and the receiver's coverage and sensitivity adequate to pick up the other aircraft's signal from whatever direction it comes.

Beacon transmission power varies from 20-250w for ADS-B / CAP1391 but it's very difficult to determine the sensitivity of the receivers on the market – my investigation suggests that it could vary between -88 to -100 dBm.

In general, the more sensitive the receiver or more powerful the transmitter, the greater the effective range between the two.

In the real world there will be a hotchpotch of different transmitters and receivers contributing to conspicuity. A low-power transmitter and low-sensitivity receiver will have a very short effective range, whereas increasing those parameters can improve it.

DIAGRAM 1

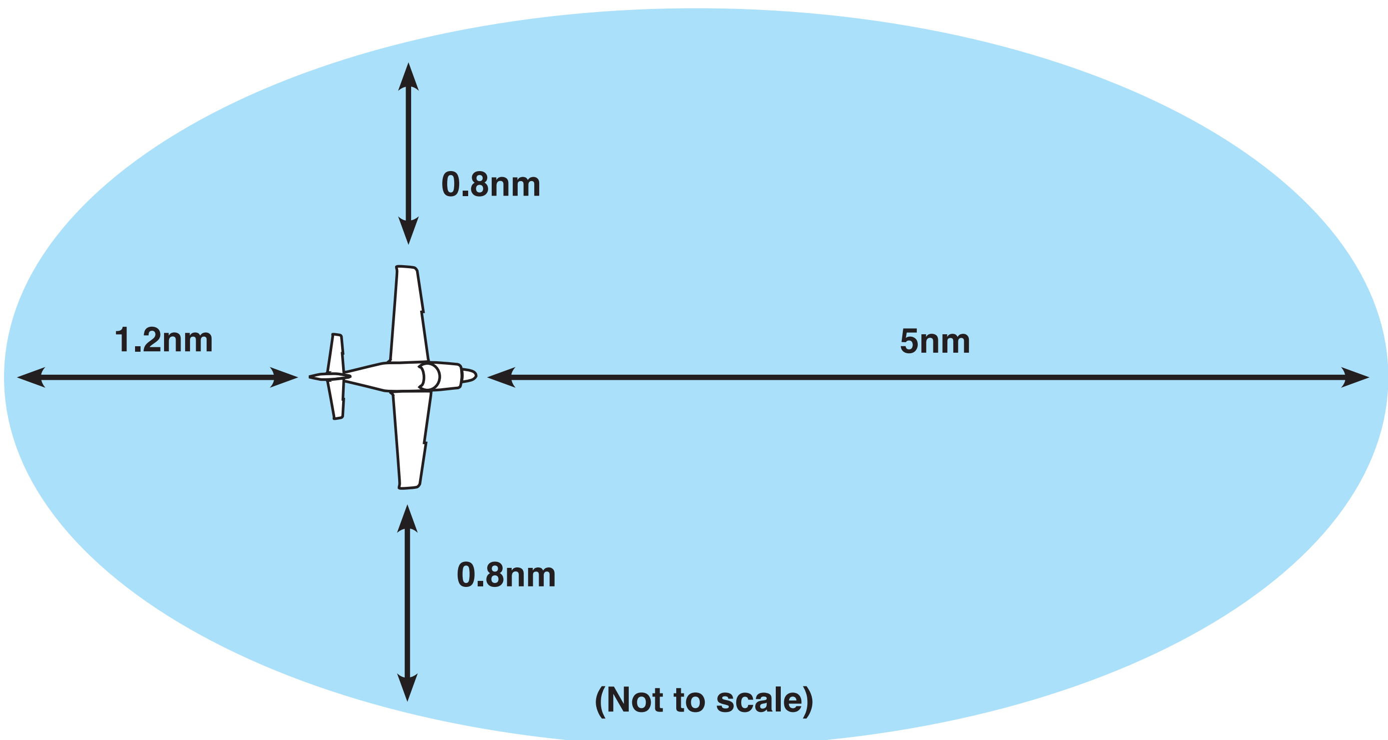
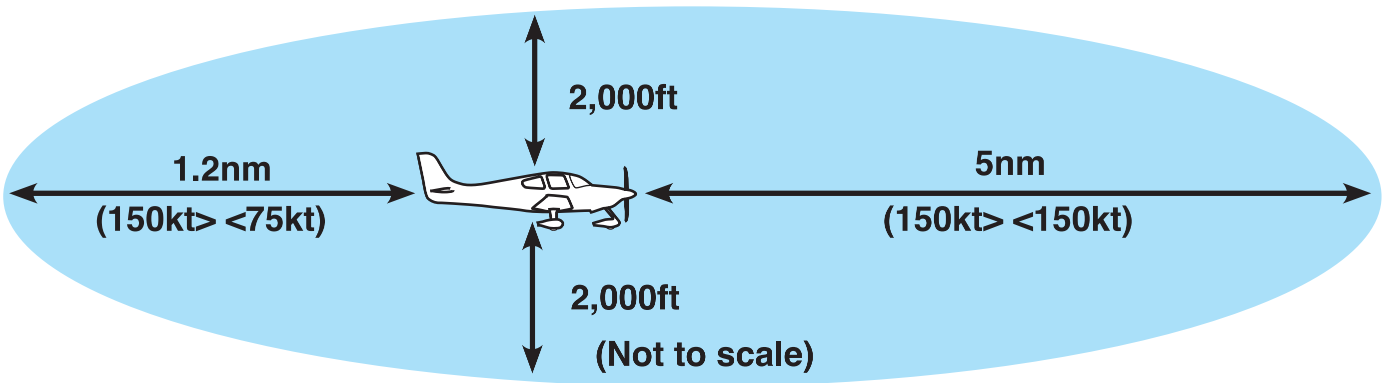


DIAGRAM 2



My Van's RV-6, G-EYOR, one-minute warning zone (with speeds).

Ergo, effective range will be a function of both aircraft's installations.

Rather than claim 'pie in the sky' ranges based on their own optimised equipment (and tests), the manufacturers need to address the issue more openly. I'd certainly go for as much power and sensitivity as I can get, to ensure my equipment works in all scenarios.

ANTENNAE

Having sorted out the electronics, getting the signal out to, or receiving it from, the sky is the next challenge, and this is done by an antenna.

It's normally an insulated brass or copper rod about 7cm-long (1090MHz ADS-B) for a monopole antenna, or 14cm for a dipole. Matching the length to the frequency is important for efficiency. For example, for 830MHz (FLARM or PA) the optimum length is 8.5cm., so expecting the same antenna to work well for ADS-B is unrealistic.

To work at all, a monopole needs to be mounted on a conducting surface (ie a metal ground-plane), such as the fuselage or an aluminium plate, whereas a dipole can just sit on the end of its cable.

It's important to understand that an antenna doesn't radiate or receive signals evenly in all directions (ie isotropic radiation), as would a light bulb, but has a distinct pattern, meaning strong signals in some directions but almost non-existent in others.

Antennae radiate or receive most efficiently in a disc or donut-shaped beam around their axis. The efficient zone of the beam widens with distance by 20-25° for a monopole or about 40-50° for a dipole.

Within its optimum beam, the antenna should achieve the predicted range of the transmission or sensitivity of the reception but, outside of that, its performance will deteriorate rapidly to a point where there's no signal at all.

Another consideration is polarisation. If a transmitter antenna is mounted vertically then, for maximum efficiency, any antenna expecting to receive its signals should also be vertical. That's referred to as polarisation, and is normally chosen to achieve the best coverage. In the case of EC, all antennae should be vertical, as any difference between transmitting and receiving antennae' relative angles (such as when manoeuvring or due to installation issues) results in a deterioration of signal level, with almost total loss as the difference becomes 90°.

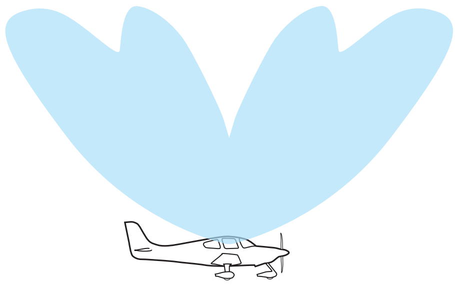
Therefore, although in ideal conditions long detection ranges can be achieved with comparatively low power and sensitivity, most of the time the equipment will be operating outside its optimum. This can only be compensated for by a significant excess of sensitivity for the receivers and power for the transmitters over that required for an optimised system.

MOUNTING AND COVERAGE

Not withstanding the theory outlined above, an aircraft is a far from ideal environment for mounting an antenna efficiently. Radio waves can reflect off or refract around an airframe in a relatively chaotic manner. If that happens, some signals may radiate in unexpected directions and others vanish from the predicted direction entirely. However, the key to effective range and coverage (transmit and receive) is still a good antenna, location and installation.

Most basic EC systems have a small antenna sticking out of a portable box. Radio waves travel in straight lines and reflect off, rather than pass through, metal or carbon-fibre, so the coverage provided by the box is very dependent on where you put it. For many, it won't be very effective in the cockpit – only 'seeing and being seen' out of the windows, as shown in Diagram 3.

DIAGRAM 3



Possible coverage provided by an in-cockpit antenna.

For my RV-6, a basic portable beacon in the cockpit could provide some forward and sideward visibility – perhaps 20 per cent of coverage.

Mounting the antenna externally on the airframe, as shown in Diagram 4, in a position that's designed to optimise the coverage and minimise obstructions and reflections, does go some way to addressing the coverage issue. However, it's also important to select the correct antenna system.

A single antenna, no matter how clever, will always have significant coverage limitations due to their radiation pattern and the potential presence of the airframe and engine between them and a target. For my RV-6, mounting a single antenna on the fuselage should provide all-round visibility on either the top or bottom but not both – perhaps 50 per cent coverage.

Mode S ADS-B certified transponders, in particular, are affected by this limitation because they're required by their approval to have a single simple antenna on the bottom of the aircraft, as shown in Diagram 5, which ›

DIAGRAM 4

The theoretical coverage provided a top fuselage-mounted monopole antenna.

DIAGRAM 5

The theoretical coverage provided by a bottom-mounted antenna, eg Mode S / ADS-B transponder.

limits coverage to the lower zone only. That's great for sending your squawk or extended squitter to ATC, but not much use for your conspicuity to an aircraft above you.

The US system of choice, UAT, addresses this problem by using a ground-base which relays the traffic data it receives from transmitting aircraft up to all the others, so it only needs downward-looking antennae. However, as previously noted, that system isn't scheduled to come to Europe! So we have to resolve the coverage problem in another way. Commercial traffic warning systems such as TCAS use multiple or 'diverse' antennae to address the problem of gaining full coverage.

Antenna diversity involves using more than one to fill in the coverage gaps. However, diverse antennae require synchronised transmitters and receivers, so they don't interfere with one another, which is more complex.

With that in mind, I'd look for a system which could at least be easily expanded to include diverse antennae. Although I'm as yet unaware of a diverse solution for *CAP1391*, there's nothing in the specification which precludes it, and some of the other manufacturers already claim it as a feature.

TESTING ANTENNA EFFICIENCY

The actual coverage provided by an antenna is notoriously difficult to measure or guarantee. 'Seeing' another aircraft on the ground, ie ramp-testing, only indicates that it's transmitting and you're receiving – it has little correlation with what will happen in the air.

One simple way of indicating how well such equipment is working in the air is to take a leaf out of the radio amateurs' book and log all traffic contacts electronically (direction and range, relative to the aircraft) and then, after sufficient time, analyse them with respect to direction. As this history builds up, you should be able to get a good idea of coverage and blind spots, and re-site the antenna, if necessary. For me, such a data log would be an essential tool to give me confidence in how well a system is working.

> **"**One simple way of indicating how well such equipment is working in the air is to take a leaf out of the radio amateurs' book**"**

One of the requirements of *CAP1391*, for the manufacturers of beacons, is to provide advice to their customers on antenna installation and performance.

I'm keen to see what this might be and how they address coverage and range advice.

MY SPEC FOR AN EC FIT

I'd like a modular product which can grow into the 'total package' that, when complete, would provide the following features:

- Beacon: A ninety per cent coverage (ie isotropic) on 1090 MHz, detectable by correctly-equipped aircraft within five miles horizontal radius and +/-2000ft of the height of your aircraft.
- Receiver: A Ninety per cent probability of a position (not proximity) warning of a conflicting aircraft's transmission on any of the candidate standards, made within a five mile horizontal radius and +/-2000ft of the height of my aircraft.
- Intercepted target data-logging, to enable antenna coverage and performance-monitoring.
- An acoustic warning connectable to the intercom system.
- An installed, radar-like display of conflicting targets, giving approximate relative bearing and height.
- Data output to a tablet traffic display (Bluetooth or Wi-Fi)
- Cockpit-selectable 'Beacon(s) Off' mode for use in Class D airspace, operated by a switch, not an app.
- Rugged, light, multi-band or broadband antenna, suitable for exterior mounting and capable of up to 190kt.
- Automatic start-up upon the application of power.

At this point, you may be thinking, "So what *is* the solution?" Well, we're not there yet! I'm well aware of the challenge that the required coverage I specified presents to manufactures, but my wish list certainly isn't pie in the sky.

I'm not suggesting any functions or features that one or another EC manufacturer doesn't already offer. However, they simply aren't all available as a single system, as of yet…

IN SUMMARY

EC is about safety, nothing more. I want to see every aircraft close to me that can be seen, and be seen by any aircraft with a receiver.

I'm one of those, now sceptical, people who replaced a perfectly good Mode A/C transponder with a Mode S and am still wondering why. So I'm not going to spend £250+ and clutter up my aircraft just to transmit into a vacuum. I'll only consider a system if it could eventually do what I really want.

CAP1391 is a broad spec and its compatibility with ADS-B is an opportunity to develop a better, more effective traffic warning system which will help us all.

The technical issues outlined herein need to be addressed by the industry and the authorities, to help convince us to take up EC. In particular, the industry must drop the 'hope and prayer' method and honestly address how these things perform, in terms of range and coverage, and what the installer must do to make it happen.

In addition, remember that EC will only begin to work effectively when most of us have it, but many won't buy it unless we believe it's going to do something for us, not just ATC and the tracking enthusiasts!

Should you buy one? As I said at the start, it depends on what you want it to do for you!

FEEDBACK

I'd like to encourage others to comment on what they might like in the way of EC, so that the CAA and industry can use our feedback and develop the system we actually want, rather than something they think we should have. After this article is published I'll be starting a blog to collate any opinions, so please email your thoughts and findings to me via *frasersi@btinternet.com*. ■

The uAvionix SkyEcho, which weighs only 200g, is an approved portable ADS-B Out solution in the UK. *(Photo: www.uavionix.nl).*