Processing and Simulating IFF Radar: A Primer and Review of SPx Software Capabilities

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Identification Friend or Foe

During World War II, with the advent of radar, it became necessary to devise systems that were capable of identifying friendly aircraft beyond visual range. Early systems relied on triangulation of a regular signal simply broadcast by friendly aircraft. An improved system was then developed that operated essentially as a transponder, sending out an omnidirectional amplified pulse in response to receiving a primary radar pulse. Thus friendly aircraft fitted with these early transponders briefly flashed brighter than other echoes on the same radar display.

Modern IFF systems still operate on the principle of a transponder sending out an omnidirectional transmission in response to some stimulus from an interrogating system. However, these systems support the ability for the enquiring system to ask different "questions" of the transponders and for the transponders to reply with information encoded within the response. The interrogating system will generally be asking listening transponders to report either their altitude or an identification code number.

As with the very first IFF systems, modern ones still rely on cooperation of friendly targets. The friendly target must be carrying a suitable transponder and that transponder must be operational. Furthermore, lack of an IFF response does not necessarily imply a target is hostile; it could simply be a friendly target without a transponder. Therefore, despite the name, IFF systems can be used to identify friendly targets positively but they cannot identify hostile targets. A primary radar is still fundamental to detecting potentially hostile targets.

On a modern IFF installation, the interrogating system sends an encoded query in the form of two pulses (P1 and P3) and the transponder on a friendly aircraft replies, reporting some information about itself. The time between query pulses P1 and P3 tells the airborne transponder what information is being asked of it. The following table (Table 1) shows the P1/P3 pulse patterns for the most common military and civilian IFF interrogations.

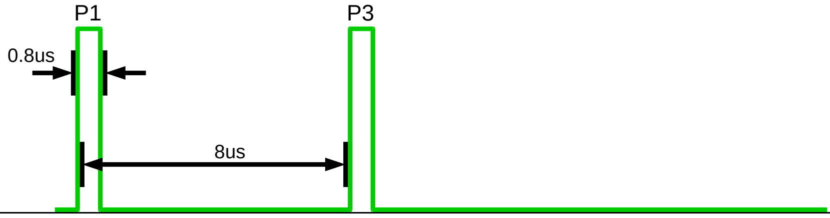
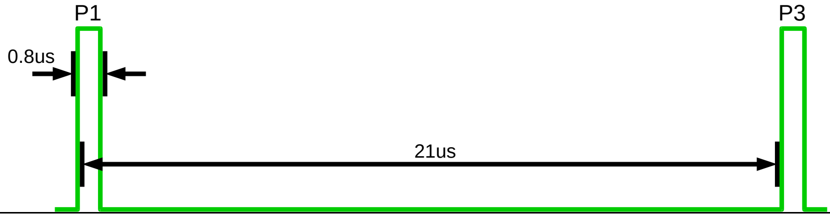
Mode	P1/P3 Pulses	Query Type
1		Military identification code
2		Military identification code
3/A		Military/ civilian identification code
C		Civilian altitude request

Table 1: Common military and civilian IFF interrogation pulse modes

The response from the transponder is a set of pulses in between two "framing" pulses (F1 and F2). F1 and F2 are always separated by the same interval and the pulses between them are only valid if they occur at fixed intervals. Figure 1 shows the pattern of possible pulses within an IFF reply, which conveys the response information. Decoding of the information requires a knowledge of the query to which it is replying.

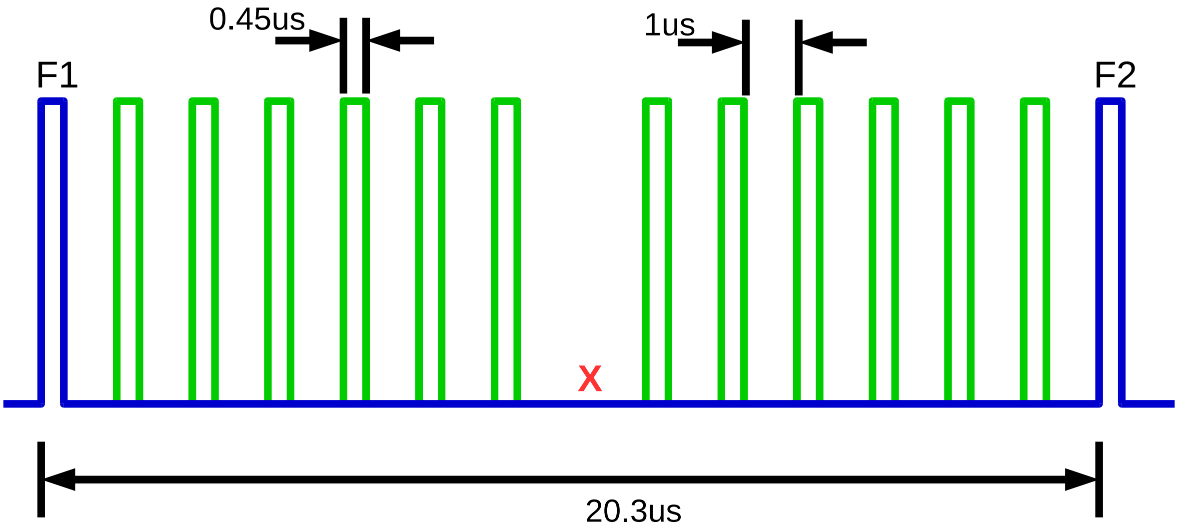


Figure 1: IFF response pulse positions, showing the framing pulses (F1 and F2) and the fixed possible positions of up to twelve pulses in between, which represent the encoded reply information.

The IFF interrogation system consists of a rotating antenna that transmits the interrogations, separated by a repetition interval, as it rotates. In general, each transponder will receive multiple interrogations as the IFF antenna beam sweeps across it. The interrogation mode may change between repetition intervals. So, it is important for the receiver within the IFF system to know the interrogation mode sequence in order to be able to decode responses reliably and correctly.

As with primary radar, the time between query pulses being sent out and a response being received gives range information. The bearing of the antenna when the response is received gives the azimuth information. Tracking of these responses from scan-to-scan can then yield speed and course information.

IFF Decoding Problems

In the real world, with crowded skies and imperfect transmissions, the responses received by an IFF interrogator may be somewhat degraded. In particular, there are two types of noise that can affect IFF video: garbling and FRUIT.

Every IFF transponder that is within range of a querying IFF system will send a response, if appropriate and if possible. The range and azimuth extent of each transponder response, as received by a rotating IFF antenna, are around 3km long and typically several degrees wide. There is therefore potential for different responses to overlap, resulting in "garbled" messages.

Garbling may be classified as non-synchronous if the responses overlap in such a way that the pulses within them do not align with the expected time intervals. Such garbling is relatively straightforward to detect and counteract. When garbling is such that overlapping response pulses fall in valid positions, this is known as synchronous garbling and is much more difficult to deal with. Both types of garbling are depicted in Figure 2.

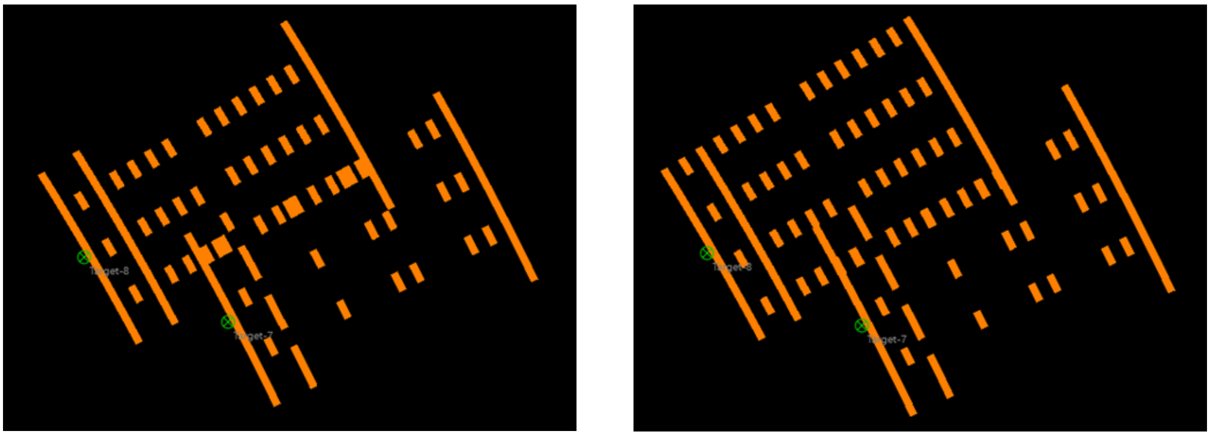


Figure 2: Non-synchronous garbling (left) of two transponder replies. The response pulses do not align with allowable positions and may therefore be resolved. Contrast with synchronous garbling (right) where the overlapping pulses are in valid positions.

It is also possible for the querying system to receive a response that was intended for another querying system. This type of behaviour results in false returns, uncorrelated in time (FRUIT). Because it is not correlated in time, i.e. between successive interrogations, FRUIT manifests itself as response pulses that are only present in one or two adjacent returns. FRUIT can be reduced in electronic circuitry by using a delay line network and comparing the pulses in adjacent returns, only accepting those that were present in at least two of the returns.

A further possible complication arises from the fact that not all transponders will respond to all interrogations. In particular, a civilian transponder will not reply to military-only interrogations (i.e. modes 1 and 2). Therefore, when the interrogation sequence is a mixture of civilian and military modes, a civilian transponder response will break up in azimuth as the military interrogations are ignored.

Software Implementation

Traditionally, IFF systems relied upon dedicated electronics to process the transponder responses and perform de-garbling and de-FRUITing, as well as the actual decoding of the altitude and identification information. This made it expensive to replace or upgrade IFF decoders.

The IFF video is often available as an output from IFF transceivers, allowing operators to view the "barcode" video and provide an extra level of reassurance. By processing the IFF video at a suitably high sampling rate it is actually possible to perform de-garbling and de-FRUITing, and to extract meaningful information, reliably. Cambridge Pixel's SPx software has been successfully deployed on projects, doing just that. It has opened up the possibility of low cost upgrades and repairs that may have otherwise involved hardware changes.

As long as the IFF video can be sampled such that a number of samples covers each pulse within the response video, it is then possible to detect when a response is garbled. If the samples from adjacent returns can be compared then the presence of FRUIT may also be detected. Comparing adjacent returns is relatively straightforward in software, especially compared to the delay line networks that are required to do the same thing in hardware.

The SPx software is capable of detecting a number of different garble modes, such as when the framing pulses are too far apart because they are the outer pulses of two overlapping replies. It is also capable of detecting where response pulses that are too wide to be valid from a single transponder reply or where response pulses occur at incorrect timeslots, relative to the framing pulses.

If the interrogation sequence results in fragmented responses, the response fragments may be very narrow and therefore potentially may be considered FRUIT and discarded. The SPx software has intelligence built-in that looks across the width (azimuth) of a transponder response, even when fragmented, specifically to reduce unnecessary removal of useful information. If the transponder replies are consistent across a gap then they may still be considered as valid responses, rather than discarded as FRUIT. Furthermore, by considering the decoded responses, the processing is also able to avoid merging fragments from different but very close transponders.

Similar processing can also help in cases where the transponder replies are corrupt on some azimuths. By comparing the decoded responses across all azimuths it is possible to make an informed decision about the validity of the information and to discard non-matching responses.

Once the IFF video has been processed to extract the range and azimuth bounds of each transponder response (i.e. the plot), as well as the encoded information contained within, the plot may be treated in a similar fashion to one derived from primary radar video. This allows for commonality within the software architecture, with tracking of primary and IFF plots performed by independent instances of the same application. A track fusion process may then receive the primary and IFF track information and compare them to determine where they correspond to the same physical target.

Flexible Modular Approach

The SPx software solution to IFF processing and tracking is modular, potentially allowing interfacing to occur at different stages of an IFF system. For example, the input to the software could be the raw transponder response video, allowing any existing IFF hardware processing to be eliminated or bypassed. Equally, the decoded responses from an existing IFF system can be taken as an input into a fusion process for correlation against, say, primary radar track data. In this case, allowing the existing IFF hardware to be retained.

Another obvious benefit of the software approach is the simplicity with which future upgrades and enhancements may be applied. As improvements are made and new algorithms are added, the modular basis of the software means that benefitting from these is simply a matter of installing the latest version of the SPx software.

In parallel with IFF video processing developments, Cambridge Pixel's capability to simulate IFF video has also been developing. Having a realistic source of fully programmable IFF video has proven invaluable during Cambridge Pixel's development of intelligent de-garbling and de-FRUITing algorithms. The ability to simulate targets overlapping to various degrees and readily being able to change IFF interrogation mode has provided a source of data that would otherwise simply not have been available.

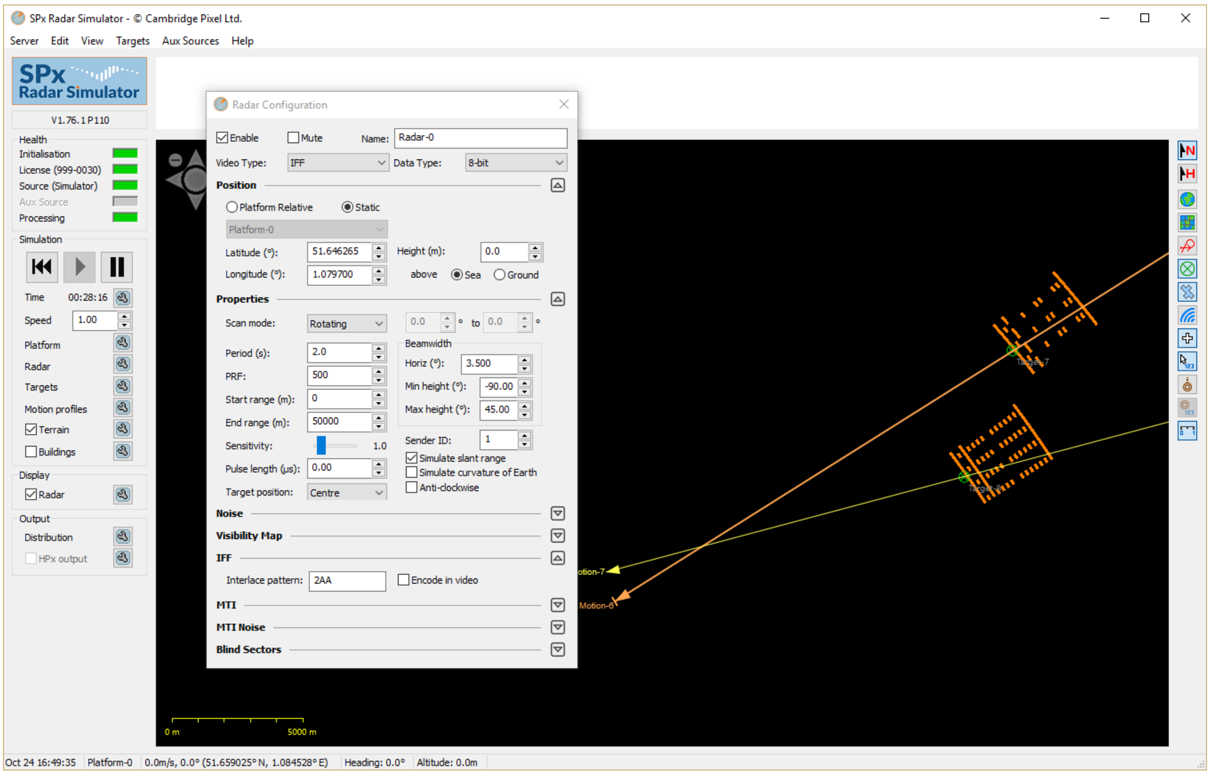


Figure 3: Cambridge Pixel's SPx Radar Simulator application generating IFF video returns

Further Reading

Reference projects:

http://www.cambridgepixel.com/news/2015-05-27-Royal-Thai-Air-Force-Selects-Cambridge-Pixel-For-Air-Defence-Upgrade.asp

Additional product information on Cambridge Pixel's products that are pertinent to this document is available as follows:

SPx Server - http://www.cambridgepixel.com/products/SPx-Server/

SPx Fusion Server - http://www.cambridgepixel.com/products/SPx-Fusion/

SPx Simulator - http://www.cambridgepixel.com/products/SPx-Radar-Simulator/

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