Auto-pRES Manual

Version	Date	Revisions
Version 100.0	06-10-2014	New version for RMB2 + VAB Issue C
Version 100.1	13-10-2014	Updating figures. Minor text edits. Mention File Manager
Version 100.2	20-10-2014	Discussion of power supply requirements; change to GPSon; contents list
Version 101.0	11-06-2015	Description of uptell functionality; change to AFGain settings as a result of move to RMB2 Issue C.
Version 101.1	12-11-2015	Corrections to screenshots and VAB photo. Active GPS antenna jumper.
Version 101.2	30-01-2016	Addition of Appendix with checklist for long-term deployment
Version 101.3	09-11-2016	Minor mods
Version 101.4	27-07-2017	Description of additional functionality (TOD sync, battery check), FTP server functionality
Version 101.5	25-05-2018	Description of additional config commands (ER_ICE, GPS_TIMEOUT, NO_IR_RETRIES, MessageTimeout), and averaging option for trial subburst.

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1. Background

Ground-based phase-sensitive radar with glaciological application has its roots in the pioneering work during the 1970s of Mike Walford and colleagues at the University of Bristol. But, with emphasis turning to sophisticated airborne systems, for some decades ground-based development took a backseat. In the late 1990s we at BAS had need of a system to measure the basal melt rates of Antarctic ice shelves. The idea was to configure an off-the-shelf vector network analyser (VNA) as a phase sensitive radar to measure the thinning of an ice column over a time interval of a several weeks or a year. Internal reflecting horizons were to provide the datum needed to remove the effect of snow compaction and accumulation between re-visits, and a network of GPS stations were to provide an estimate of vertical strain in the ice needed to extract the melt rate from the thinning measurement.

In the event, the performance of the system was better than anticipated, to the point that the vertical strain, compaction rate and basal melt rate could all be extracted from a pair of radar observations separated by a few days, weeks, or a year, depending on the size if the signal. For the determination of basal melt rates, vertical strain rates are required merely as a correction, but glaciologists have since used the technique on grounded ice to make measurements of vertical strain rate in their own right.

Oceanographers concerned with the interaction between ice shelves and the ocean struggle to retrieve time series reflecting the conditions in the sub-ice shelf cavities. Until now, the only technique available has been to drill access holes and deploy oceanographic instrumentation beneath the ice. This is a logistically expensive endeavour, and only a handful of sites have been instrumented in this way. The measurements of time series of basal melt rates offer a direct indication of ice ocean interaction, and an excellent proxy for sub-ice shelf conditions. Using radar techniques to provide such a time series can be achieved only by leaving an instrument operating autonomously for the desired period of observations – perhaps a few years in order to recover seasonal melt signals and perhaps hints of interannual variations.

A VNA is an expensive, heavy, general-purpose piece of laboratory test equipment that for best results requires laboratory-like conditions and a portable generator to provide the necessary power supply. Clearly pRES in its traditional form could not be left to run autonomously. Hence the development of ApRES. In 2009 we approached Professor Paul Brennan at University College London Department of Electronic and Electrical Engineering about the options for a low-power, low-cost replacement for the VNA-based pRES. A year of NERC funding resulted in Dr Lai Bun Lok building a prototype system that was trialled in the Antarctic in 2011-12. The first PCB-based system (RMB1) was developed during 2012, and was managed by a Micro-Robotics embedded controller on a purpose-designed controller board (VAB). Several instruments were produced and deployed in Antarctica and Greenland. The second version of the radar board (RMB2) was developed during 2014.

ApRES appears to outperform pRES, the instrument is robust to -40°C, it is relatively inexpensive and very lightweight. This all means that we can envisage many instruments being deployed concurrently to obtain a more synoptic view of the changing melt rate of an ice shelf's base. As a glaciological instrument used in an attended mode, the superior signal to noise performance means that internal layers can be monitored at depths greater than possible with pRES.

An additional capability of ApRES is MIMO operation. This is an optional extension that involves multiple antennas (up to 8 Rx and 8 Tx) being active sequentially to offer imaging capability at a level that depends on the setting. A discussion of using the multiple antenna mode will appear as an annexe to a future version of this manual.

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October 2015.

2. Requirements

- Computer with Ethernet port and web browser
- Radar unit (ApRES)
- Power cable
- Battery or PSU (6*-13V, 1.5 Amp maximum drain at 6V)
- Ethernet cable
- 1 or 2 SD-cards (minimum of 1) + card reader.
- Antenna cable x2
- Antenna x2

* But see comments on battery and Power Supply Requirements below

If data processing is to be undertaken in the field, a copy of Matlab, and the Signal Processing Toolbox will be required on the PC to run the processing scripts. If calculation of vertical strain rates or melt rates is required in the field, the Statistics Toolbox will also be needed on the PC. As at this stage in the development updates to the radar control software are likely to be needed, it will be important to have the supplied serial interface cable etc (see below) and a copy of the Venom IDE (Integrated Development Environment) installed on the PC.

If leaving the instrument in unattended mode, over the winter, for example, a few other items are required:

- Antenna mast (eg, 4-m glacio-pole)
- Iridium+GPS antenna bracket
- GPS antenna and cable, and, if Iridium comms are to be used, Iridium antenna and cable.
- Hose clips or equivalent to attach the antenna bracket to the pole
- Cable ties to tidy up the GPS and Iridium cables
- A small sheet of plywood: the instrument should be buried to a depth that will prevent the temperature it experiences dropping below -40°C. It would be wise to take a small sheet of plywood or equivalent to cover the instrument before re-filling the hole with snow.
- Some way of marking the site (bamboos with large flags).

A note about SD cards. The system has been tested with cards up to 16GB. We have had problems with Transcend 16GB cards, and therefore recommend avoiding them. SanDisk Extreme Pro seem to work well, but are rated only to -25°C – fine for most summer use and we have used them successfully to -40°C. Panasonic make an MLC -40°C, 16GB card, which is relatively slow, but good value. High speed cards are not required for this application. The cards must be formatted as FAT32.

3. Overview

The instrument has two modes of operation: Attended Mode and Unattended Mode. On power-up, the configuration file (config.ini) is read from the SD card in Slot 1 (the slot nearest the USB connector on the controller board) and the Ethernet link is tested. If the Ethernet is active (ie a powered-up PC is connected), or if the config.ini file indicates to do so, the radar enters Attended Mode, and will remain in that mode until the power is cycled (or, equivalently, the reset button on the controller board is pressed), when the config file will be re-read and the Ethernet link tested again. Attended Mode would be used for initially setting up Unattended operation, or for using the radar as a survey instrument – moving from one location to another to obtain measurements from a series of points, to be repeated at some time in the future.

Unattended Mode is entered if no Ethernet link is detected and if the config file is not set to send the radar to Attended mode. In this case all the details of the radar's configuration are determined

by the contents of the config file. Initially running in Attended Mode allows the operator to determine the correct settings to be placed in the config file for future Unattended operation. When running in Attended Mode, the config.ini file is used to set the initial radar parameters, some of which can be overwritten from the connected PC.

In Attended Mode, the PC needs no software other than a browser. In that mode, the radar is configured as a webserver.

An Iridium modem can be used in Unattended Mode to allow periodic transfer of a small amount of data and housekeeping information. It can also be used to reconfigure the instrument remotely. The Iridium transceiver has an external antenna that is mounted on a bracket

A GPS receiver is used in both Attended and Unattended Mode to provide an accurate time, and also location information that is used to provide metadata in the Attended Mode data file. Location information is included in Iridium messages. In Attended Mode an internal antenna can be used. For Unattended Mode, an external antenna is mounted on the antenna bracket, beside the Iridium antenna. Usually, an internal antenna would be active (ie, it uses a low noise preamplifier in the body of the antenna). The standard GPS antenna used during unattended operation is passive, and so an active antenna requires a power supply. This can be provided by setting a jumper on the VAB (the controller board – see photograph at the end of this document).

4. ApRES radar operation

The radar transmits a tone that has a nominally constant amplitude (a nominal power of 20dBm, or 100 mW), but whose frequency ramps linearly from 200MHz to 400MHz over a 1-second interval. This is a single chirp. The chirp received from a reflector arrives a short time later, and so is always at a frequency slightly lower than the tone presently being transmitted, the difference in frequency being linearly dependent on the range of the target.

Mixing the received signal with the transmitted signal generates sum and difference frequencies, and the difference frequency (anything from 0 to a few kHz) can be selected by an appropriate filter and recorded. Calculating the spectrum of that signal then gives the standard "A-scope" display.

In the case of ApRES, the phase of the transmitted tone is carefully defined, and by tracking the phase through the processing it is possible to process the data using phase-sensitive techniques.

The output power of the radar is fixed, but an attenuator in the receiver chain and an adjustable gain amplifier in the low frequency "de-ramped" signal can both be adjusted to ensure that a sufficiently strong signal is being recorded, without overloading any of the circuitry. Up to four different attenuation levels can be used in sequence, with the radar automatically cycling through the settings. So if 60 chirps were to be recorded, 15 could be acquired using each of four different combinations of attenuators. In the case of four different settings, that would give a "sub-burst" that was four chirps long. When specifying the number of chirps to be recorded, the operator actually specifies the number of sub-bursts. If only one attenuator setting is used, a sub-burst is equivalent to a chirp. Although this functionality has been retained, that is, the ability to record the chirp with a sequence of up to four attenuation and gain settings, it is recommended that only one attenuator/gain setting is used.

5. Attended Mode

Connect the Ethernet cable to a computer.

Insert an SD card in the Primary SD card slot (the slot nearest the USB port on the VAB – see photograph). In fact, it's not important which slot is used, but making a habit of using the Primary is good practice. When two cards are present, the Primary slot is checked first for a config file, which is copied to the Secondary card, overwriting any config file present.

Connect the antennas.
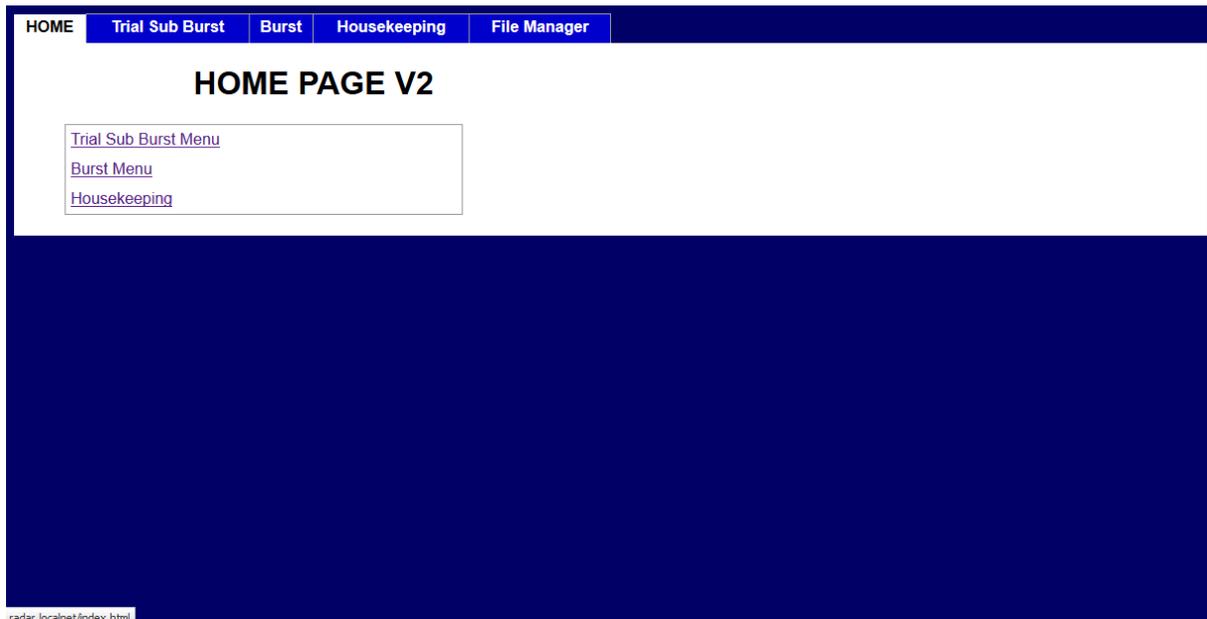
Ensure the PC is powered-up, then switch on the radar.

Start a browser on the PC

Navigate to *radar.localnet*. At this point the radar will be functioning as a web server, and the radar controller screen should be displayed. If the browser has problems resolving the name, and all else has failed, then the PC can be set up with a fixed IP address of 192.168.1.1.

Click <Housekeeping> and check the radar's clock. This can be set manually or, if a GPS antenna is connected and a satellite has been found, it can be synced to the GPS time. This screen refreshes every 2 seconds. If the GPS fix is good enough, a location will also be displayed.

The battery voltage is displayed on the same screen.

From this screen the config.ini file, if it exists, can be downloaded from the SD card. A new config.ini file can be uploaded to the SD card, overwriting any existing version. For the new configuration to be used, the radar needs to be restarted, or, equivalently, the reset button on the controller board needs to be pressed.

There is also a Test Iridium button. See Iridium Communications section below for details.

Before recording a full burst of data it is necessary to check the attenuator levels by doing a "trial sub-burst".
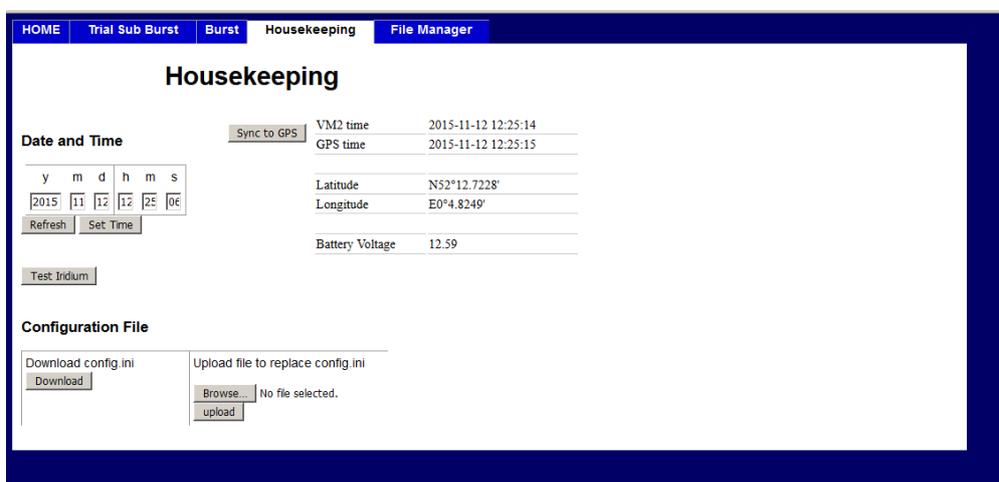
Click <Trial Sub-Burst>, and then select the number of attenuator settings that you wish to try (1 to 4), followed by <update>. Fill out the attenuation values – see the later section discussing criteria for the selection. There is also an "Average" value, defaulted to 1, that can be changed. Usually, we use only one chirp at each attenuator setting for the Trial Sub-Burst, as the function of the trial is to help select the most appropriate attenuator and AF Gain settings. However, it can occasionally be convenient to try to pull a weak bed echo out, in which case a larger number of averages can be
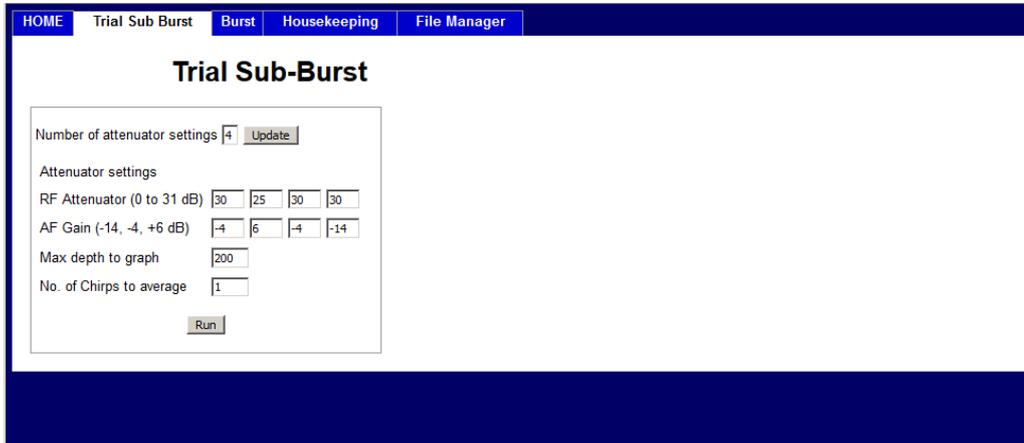
tried. This could be particularly useful if the operator does not have access to a computer with Matlab. Note, though, that this is slow. It will require about 40 seconds to do an average 10 chirps. Click <Test>. The PLL light on the side of the instrument will light while the various chirps are being performed (up to 4). Four histogram panels will be displayed. The histogram will indicate the dynamic range of the analogue to digital converter (ADC) that is being occupied by the signal. For example, if the signal is spending most of the time hard up against the positive and negative limits (ie, the ADC is clipping the signal), then the histogram will begin to develop a "W-shaped" character. If it is spending all its time around zero volts, then there will be a very narrow sharp peak at the centre of the histogram. Ideally, the graph would show a gentle bell shape, with no turning up at the upper or lower extremes. In the case of a very strong and clear basal reflector, the signal being recorded takes the form of a clean sinusoid and there will be a dip in the centre of the histogram: a sine wave has few points around zero.
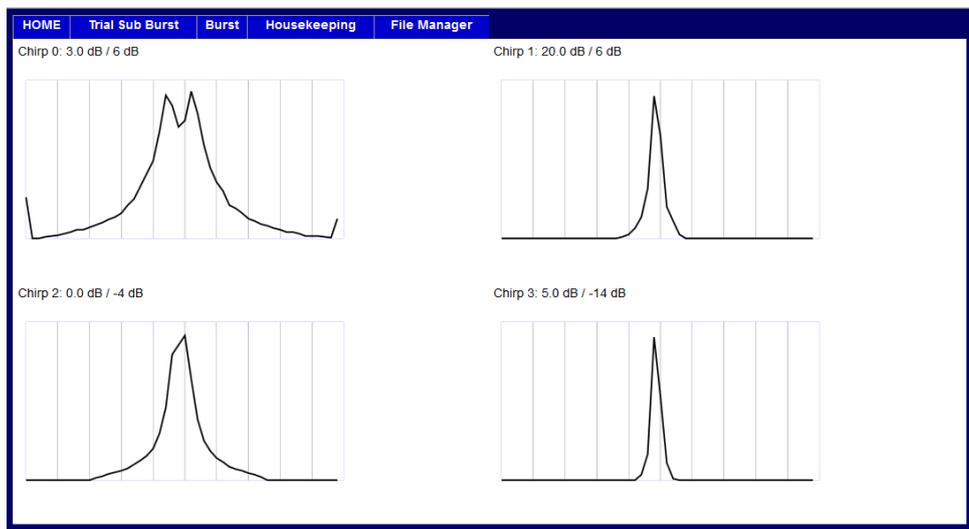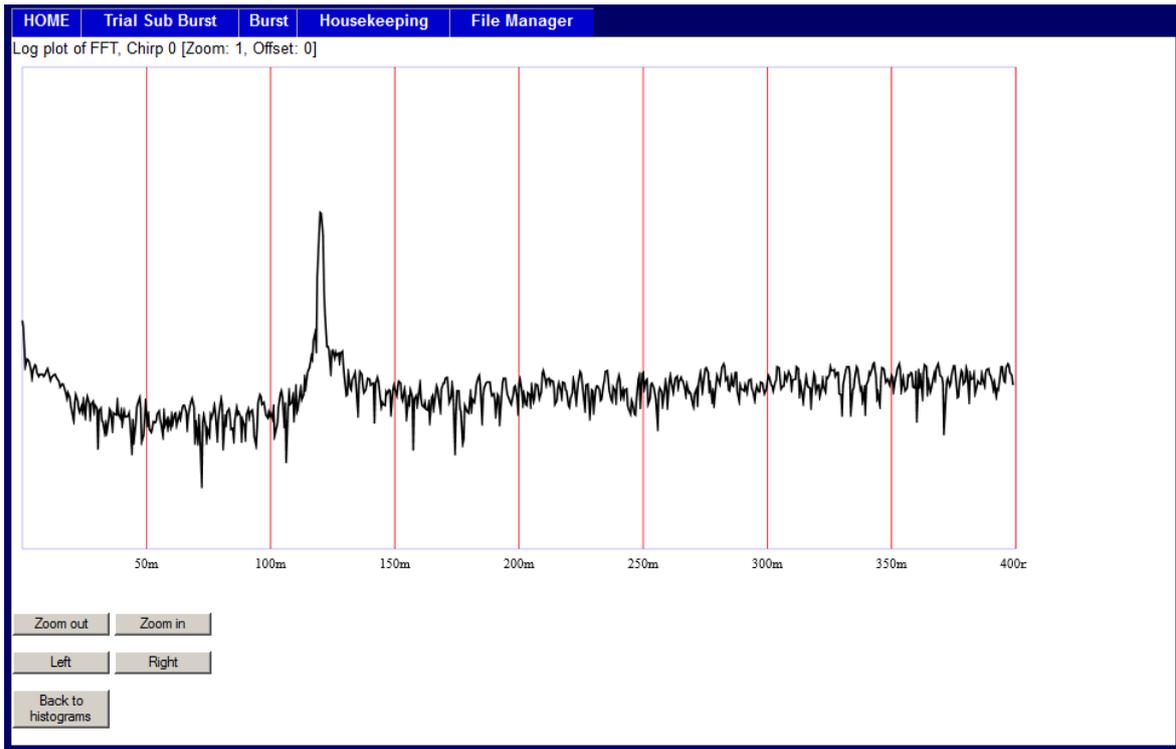
Click on the histogram with optimal characteristics, and wait (about 10 seconds – it's a slow processor…) until the browser displays a range plot of the chirp. The plot can be zoomed and panned using the buttons at the bottom of the screen. The maximum (default) depth for this plot was set on the Trial Sub-Burst page.

When satisfied with the attenuator selection, navigate to the Burst page and set up the required attenuator settings and the number of sub-bursts required, and then click <run>. Remember that the total number of chirps acquired is given by (number of attenuator settings selected) x (number of sub-bursts). So, if two attenuator settings have been selected, and 100 sub-bursts have been requested, the total time for the burst will be 2 x 100 x 1.2 seconds, or around four minutes. In a typical ice shelf situation, with a few hundreds of metres of ice, a single attenuator setting with 20 to 100 sub-bursts should be more than adequate for getting melt rates, taking a minute or two in total. During the burst, a progress screen is displayed with the chirp count. This screen updates

every 2 seconds.

After the burst is complete, the data file will be downloaded via the browser to the computer's filing system. A copy is retained on the SD card, under a sub-directory named "survey". If a failure occurs during download, the copy will have already been safely stored on the SD card during burst acquisition. Data from Trial Sub-Bursts are discarded. In Attended Mode, a copy is not made on the second SD card (if present) – the assumption is that the data will be backed up on the connected computer.

A simple file manager is available under the final tab. This allows the user to inspect the contents of the master SD card and download data files, but will not allow upload or deletion. Be aware that download speeds are slow: files larger than a few MB in size would more conveniently be copied by removing the card and inserting in a card reader.

| HOME | Trial Sub Burst | Burst | Housekeeping | File Manager |

Directory of /

Date	Size	File/dir
2014-10-13 15:44:06	262144	testfft.dat
2014-10-13 16:13:58	1251	CONFIG.INI

6. Unattended Mode

Typically, a period of unattended operation would be preceded by a quick check in attended mode to ensure that the attenuators were appropriately configured, the clock set, and that the radar was working properly. The config.ini file can at this point be downloaded into a text editor, modified to suit the desired settings, and then uploaded onto the SD card. The radar should then be switched off, the Ethernet cable disconnected, and the instrument then turned on again, when it will start up in unattended mode. The operation of the instrument is then determined by the contents of the config.ini file.

The contents of an example file are copied below, followed by a discussion of the various elements. This effectively covers unattended operations.

```
; Configuration file for ApRES
; ***************************
;
;   Checking for an Ethernet connection. If present, go to server mode.
;       0 Never check, never start the webserver
;       1 Check on power up, and start the webserver if active (default)
;       2 Check on start up and before each burst; start the webserver if active
;       3 Never check, and always start the webserver
;       4 Check on power up, and start the webserver if active. Perform
```

```
;        SAF data reduction etc as described in manual
;     5 As (4) but no data reduction. See manual.
;
CheckEthernet=1
;
;   Number of sub-bursts in a burst (>=0)
;   Default=10
NSubBursts=20
;
;  Are all the chirps from this burst to be stored individually (0 - default),
;  averaged (1) or stacked (2)?
Average=0
;
;   Burst repetition period (integer seconds) (>0).  Interpretation depends
;   on IntervalMode.  If IntervalMode = 0 (default), RepSecs is time from
;   start of one burst to the start of the next.  If IntervalMode = 1,
;   RepSecs is interval between end of one burst and start of next.
;  If IntervalMode = 2, the bursts are synchronised to the time of day.
RepSecs=3600
IntervalMode=0
;
;   Number of samples per burst; default=40,000
N_ADC_SAMPLES=40000
;
;   Number of chirps to be discarded at the start of each burst.  Default = 0.
Settle_Cycles=0
;
;   Maximum length of data file before another one started (>=1,000,000)
;   Default=10,000,000
MAX_DATA_FILE_LENGTH=10000000
;
; Whether a logging file is to be maintained (default = no (0)).
LOGON=1
;
;   WatchDog task behaviour. Time in seconds of operation after which the
;   radar will be reset.  Assumption is that a fault has occurred if radar
;   is active for longer than this time.  Watchdog does not operate in
;   attended mode.  If Watchdog time is set to 0, then the default of 3600
;   seconds is used.  If set to -1, then Watchdog task is disabled.
WATCHDOG_TASK_SECS=3600
;
;   In unattended mode, does the radar sleep between bursts (default, 0),
;   or does it wait (1).  In the sleep case the system is powered down
;   between bursts and draws a low current (<100uA at 12V). Otherwise system
;   remains powered and draws a significant fraction of an amp.
SleepMode=0
;
;   Time out for GPS receiver for each burst (0-255 seconds)
;   Default is 0, which means do not attempt to obtain fix before each burst.
```

GPSon=100

;

; **Time out for GPS receiver while formatting SBD messages. This is likely to be**
; **longer than GPSon (default is 120 seconds)**
GPS_TIMEOUT=120

;

; **Value for relative permittivity of medium (usually ice). Default is 3.18**
ER_ICE=3.18

;

;   **Undertake daily housekeeping (GPS clock check, Iridium exchange and**
;   **memory card check? (1 = yes, 0 = no)**
Housekeeping=1

;

;   **If GPS fix obtained during daily housekeeping or a data uplink, synchronise**
;   **radar clock to GPS time (only if Housekeeping=1)? (1 = yes, 0 = no)**
SyncGPS=1

;

;   **Is Iridium messaging enabled? (1 = yes, 0 = no)**
;   **Default = 0**
Iridium=1

;

;   **Number of retries for Iridium messages. Default is 3**
IR_NUM_RETRIES=3

;

;   **NData determines the timing of data uplinks via Iridium. Default = 0: no uplinks**
;   **See data uptell section.**
NData=0

;

;   **Triples defines the sequence of depth intervals to be used when reporting data**
;   **See data uptell section.**
Triples=100,5,300,300,25,700,835,3,850

;

;   **MessageTimeout relates to the SBD data messages. It is entered as an integer**
;   **number of hours. See details below and uptell section.**
;   **A values of 0 (default) disables the functionality.**
MessageTimeout=0

;

;   **Number of combinations of attenuator settings to be used**
nAttenuators=1

;

;   **Attenuator setting sequences for attenuator 1 (dB) (>0, <=31.5)**
;   **Defaults=30dB.**
Attenuator1=20,0,0,0

;

;   **Gain setting for deramp (AF, or audio frequency) amplifier (-14, -4, 6)**
AFGain=-4,0,0,0

;

;   **When used in attended mode, and doing a Trial Sub-Burst, the maximum**
;   **depth that is displayed on the FFT (A-scope) display. This can be**

```
;   overwritten from the browser. In Unattended Mode, controls SAF data
;   reduction.  See manual for details.
maxDepthToGraph=500
;
;   If first BatteryCheck parameter = 0.0, no battery check is performed.
;   Otherwise, parameters determine battery check.
BatteryCheck=10.2,11.5
;
;   Very much for the advanced user. The DDS programming strings.
;   These strings are set by defaults in the instrument and, like the
;   rest of the parameters in the config file, do not need to be set here.
;   They are included for completeness.  See main text.
;Reg00="00000008"
;Reg01="000C0820"
;Reg02="0D1F41C8"
;Reg0B="6666666633333333"
;Reg0C="0000431C0000431C"
;Reg0D="13881388"
;Reg0E="08B500004CCCCCCD"
;
; End of configuration file
; ************************
;
```

Some additional notes on the various parameters in the config file:

CheckEthernet: If set to zero, the Ethernet port is not checked on power-up. If set to one (default), the port is checked on power-up (or reboot), and goes into webserver mode if the port is active. If set to two, the port is checked both on power up, and before every burst; webserver is initiated if the port is active. If set to three, the port isn't checked, and the radar goes into webserver mode on power-up. If set to 4, the instrument will check the port on power-up and, if active, will go into webserver mode. It will also check the port for activity after each burst, and if the port is active, it will go to FTP server mode. If the port then becomes inactive (it is checked every second) the FTP server will be stopped and the radar will carry on in normal unattended mode. If another burst becomes due during the FTP server activity, the server is aborted and the burst is acquired. If set to 5, the processing is the same as for (4), except that no data reduction is performed. See section below on SAF data processing.

GPSon: Defaults to zero. If set to a non-zero integer, from 1 to 255, each time a burst is initiated, the GPS module is activated. GPSon then indicates the time in seconds allowed for a fix to be obtained. If successful, the GPS location, GPS time and the radar's system time at the time of the fix are stored in the data header for the burst on the SD card. Should be set to zero if no GPS antenna is connected, or if there is some other reason to think a fix will not be obtained. The module remembers the satellite constellation between fixes: after a fix has been obtained, the module usually requires only a few seconds to reacquire the satellites. So even if a long period is allowed by GPSon (eg 30 seconds), it would be expected to take only a few seconds before each burst to get a fix after the first fix has been obtained.

RepSecs: If IntervalMode = 0, ensure that the repetition interval is greater than the length of time for the acquisition of an entire burst. If it is shorter, then the radar will continue with an uninterrupted series of bursts, and it is likely that it will not be possible to switch off the unit without losing the final open data file. To estimate the length of the burst, assume that there will be at least 10 seconds of overheads associated with starting up the radar. So the total time = *NSubBursts* *

nAttenuators + 10 seconds. Setting IntervalMode to 1 means that a RepSecs-long delay will be implemented between bursts. If IntervalMode is set to 2, the bursts are synchronised to the time of day. In that case, when the instrument powers up in Unattended Mode it immediately goes through its start up procedure and carries out a burst, and then locks on to the time of day such that the next burst will start an integer number of RepSecs before midnight. So, if RepSecs is 3600, every burst after the first one will be initiated on the hour.

If the total time for a burst lasts longer than the Watchdog timeout interval, which defaults to 3600 seconds, the system will automatically reset itself. This would effectively limit the number of chirps per burst to around 2180. Note that the Watchdog Timer timeout can be adjusted with the WATCHDOC_TASK_SECS value, and that the Watchdog is disabled during Attended Mode operation.

N_ADC_SAMPLES: determines the number of samples per chirp recorded by ADC. Under most circumstances this should be left unset to allow the radar to pick its own value. For normal use, N_DC_SAMPLES will be set to 40000 by the radar. Advanced users might want to change it if they are reprogramming the DDS characteristics, but even then the radar will pick the most appropriate value.

Settle_Cycles: number of chirps to be discarded at the start of each burst. As the radar components warm up, there is a small change in phase delay through various components. If burst averaging is enabled, it might be useful to remove the first few chirps from the average by setting Settle_Cycles greater than zero. If averaging is not switched on, there is little advantage to discarding the first chirps in a burst – it can be done during post-processing.

MAX_DATA_FILE_LENGTH: Before each burst is recorded the length of the file is checked and, if greater than *MAX_DATA_FILE_LENGTH*, a new file is started. Very large data files should be avoided for two reasons: if for some reason the file is corrupted, fewer bursts will be lost if the file is shorted; and very long files incur time overheads that can run to many seconds while the file is opened and the end of file is found. Very short files are fine, but there will be a lot of them. Each time unattended operation is initiated a new subdirectory is created on the card to hold the files associated with the sequence of bursts.

MAX_SAF_FILE_LENGTH: Before each SAF dataset is saved to the cards, the length of the file is checked, and if greater than MAX_SAF_FILE_LENGTH, a new file is started.

Average: default of 0 means that all chirps are recorded as 2-byte unsigned numbers. If set to 1, all chirps from each burst are averaged and stored in the same format. If set to 2, all chirps from each burst are stacked (summed) and stored as a 4-byte unsigned integer.

nAttenuators: this actually means the number of attenuator settings to be used, that is, the number of chirps in a sub-burst (assuming not in MIMO mode – see below). If averaging is enabled (*Average* ≠ 0), all chirps in a burst are averaged together. Averaging should not be used with when multiple attenuator settings are used.

Attenuator1: The values, in dB, for each of up to four settings for the attenuator. Only the first *nAttenuators* values will be used.

AFGain: The values, in dB, for up to four settings for the gain in the deramp amplifier. Only the first *nAttenuators* values will be used. Values are either -14, -4 or +6 dB. If set to a negative value less than -4, it will be coerced to -14 dB, if greater than -4 but negative, -4 will be used. If zero or positive, it will be coerced to +6 dB.

LOGON: Set to 1 to enable the writing of a log file. This is a text file called Log.txt that will be created and maintained on both SD cards. It records the operation of the radar.

SleepMode: Set to 0 by default. This will cause the instrument to power down to minimal current draw between bursts. If set to 1, the instrument will not power down between bursts. This is useful to avoid any warm-up artefacts at the start of each burst to maximise precision, but unfeasible for long term deployments. This has no effect during Attended mode. A difficulty is that the PLL light

will not be extinguished between bursts, and there is a danger that the radar will be switched off during a burst and the final data file might be corrupted.

Housekeeping: Relevant only in Unattended mode. Set to 0 by default. If set to 1, daily housekeeping activities will take place at the end of the first burst after midnight. Iridium communications will be attempted (see below), and the SD cards will be checked and any detected errors will be repaired.

GPSSync: Relevant only if housekeeping is enabled. Default 0. If set to 1, during housekeeping activities the radar's internal real-time clock will be synchronised with a valid GPS time.

Iridium: Relevant only if housekeeping or data uplinks are enabled. Default 1. If set to 1, an exchange of Iridium SBD messages is attempted during housekeeping or data uplink activities.

NData: If Iridium has been set to 1, and the instrument is in Unattended Mode, then an uplink is attempted every Ndata bursts. So NData=1 will cause an uplink every burst. NData=24 will cause a daily uplink if RepSecs is set to 3600 seconds. NData=0 will disable data uplinks.

Triples: Defines which depth intervals are reported in the data uplinks. This consists of a series of concatenated triplets of numbers on one line. Eg Triples=200,15,300,300,25,600,650,4,690. Each triple is treated in a similar way to the Matlab xmin:dx:xmax syntax. So the first set of depth intervals in the example would be 200 to 215 m, 215 to 230 m, 230 to 245 m etc up to 275 to 290 m. The maximum number of triples is 4, and the maximum total number of depth intervals is 64. The example would report on 28 intervals in total. See section on data uptells for further details, and for the content of the data messages.

MessageTimeout: This refers to SBD data messages. Data messages are kept for MessageTimeout hours until they are either successfully sent, or else MessageTimeout hours elapse, when they are deleted. See uptell section for details.

BatteryCheck: Two parameters. If parameter 1 = 0.0 (default), no battery check is performed. Otherwise, if the battery voltage, checked just prior to the burst, is below parameter 1, then the burst is not executed and the radar sleeps until the next time a burst is due. The battery voltage must rise above parameter 2 for a burst to be executed. If the battery measurement is below 1.0 V, the voltage monitoring is assumed to have failed and the battery check is disabled.

maxDepthToGraph: In Attended Mode, the default maximum depth that will be displayed when test chirps are processed for viewing via the web server. This can be over-ridden from the browser. In Unattended Mode, this determines the maximum depth of signal saved in the file in the SAF directory. See section below on SAF data processing.

ER_ICE: This is the value used by the radar when calculating the range, during the trial sub-burst processing. It is also used when interpreting the depth intervals for SBD data messages.

GPS_TIMEOUT: the maximum time in seconds that the radar will wait for a GPS fix to be obtained during SBD message processing (either housekeeping or data messages).

IR_NUM_RETRIES: The maximum number of attempts used to make contact over the Iridium system. This is not to be confused with the MessageTimeout. IR_NUM_RETRIES attempts will be made every time the radar attempts to send an SBD message. If several SBD messages are being sent at one time (as a result of there being a backlog due to previous unsuccessful attempts), only IR_NUM_RETRIES will be allowed before stopping attempting to send messages.

Reg00 to ***Reg0E***: These define the nature of the chirp transmitted by the radar. A Matlab tool is available that will allow the chirp properties to be changed. The tool appends the relevant lines to the end of a config.ini file. Those lines are then used on power-up to overwrite the default chirp configuration.

Once the radar has been switched on in unattended mode, there will be a delay of a few seconds, and then the PLL light will come on, indicating that the first burst is underway. That delay might be longer if GPSOn>0, as the GPS will take up to GPSOn seconds to get a GPS lock before starting the burst. Once the burst has finished, the red light will be extinguished. When recovering a radar that

had been deployed in unattended mode, if a burst is underway wait until the burst has finished and the PLL light is extinguished before switching the system off. This should remove the risk of damage to the final data file.

Note that the format of the active (non-comment) lines in the config.ini file must remain exactly as given above (including no white space around the "=" sign), although the capitalisation of the parameter names is not significant.

7. Data file format

The data files consist of a series of bursts, each burst comprising a burst header in ASCII, and a sequence of sub-bursts, in binary, each sub-burst consisting of *nAttenuators* chirps. The chirps have no individual header, which means that if there are is more than one chirp in a sub-burst, the value of the attenuator settings cycles through the values in the configuration information, that is, the values in the config.ini file, updated by an ir_config.ini file, should it exist on the SD card. As an ASCII sequence, the burst header can be read in a text editor and has the following format:

*** Burst Header ***
Time stamp=2014-10-06 08:43:52
RMB_Issue=2c
VAB_Issue=C
SW_Issue=102.0
Venom_Issue=20141002
AlwaysAttended=0
NSubBursts=20
NData=3
Triples=100,5,300,300,25,700,835,3,850,0,0,0
Average=0
RepSecs=3600
CheckEthernet=1
N_ADC_SAMPLES=40000
MAX_DATA_FILE_LENGTH=10000000
ANTENNA_SELECT=0
nAttenuators=1
Housekeeping=0
GPSon=1
SyncGPS=0
Iridium=1
WATCHDOG_TASK_SECS=3600
IntervalMode=1
Attenuator1=20,0,0,0
AFGain=-14,0,0,0
TxAnt=1,0,0,0,0,0,0,0
RxAnt=1,0,0,0,0,0,0,0
maxDepthToGraph=500
SleepMode=0
LogOn=1
Settle_Cycles=0
Reg00="00000008"
Reg01="000C0820"
Reg02="0D1F41C8"

```
Reg0B="6666666633333333"
Reg0C="000053E3000053E3"
Reg0D="186A186A"
Reg0E="08B5000000000000"
SamplingFreqMode=0
Settle_Cycles=0
BatteryCheck=0.0,0.0
ER_ICE=3.18
GPS_TIMEOUT=120
IR_NUM_RETRIES=3
MessageTimeout=0
Latitude=0.
Longitude=0.
GPS_Time=0
VM2_Time=0
Temp1=20.8437
Temp2=21.0312
BatteryVoltage=6.543

*** End Header ***
```

8. RF Attenuator and AF gain setting

The first stage in deciding attenuator settings is to ensure that the ADC is not clipping, as described in the "Attended Mode" section above. The next stage is to ensure that no component in the receiver chain is near to saturation, and this is most likely to be caused by direct breakthrough between the TX to the Rx antennas, which will feature as high amplitude, short range signals.

For the skeleton slot antennas, the expected breakthrough would require a minimum attenuation of around 16dB in attenuator 1.

9. Iridium communications

An Iridium modem is incorporated in the radar system.

9.1   Housekeeping messages

At the end of the first burst that finishes after midnight, a set of daily housekeeping tasks are performed, assuming the housekeeping tasks have been enabled in the config.ini file (*Housekeeping=1)*.

First, the GPS receiver is activated and a period of up to three minutes is allowed to obtain a fix. If a GPS time has been acquired, the radar's internal clock is optionally synchronised with the GPS time, depending on the setting of *SyncGPS* in the config.ini file.

Depending on the setting of Iridium in the config.ini file, a message is assembled to be sent via Iridium. The message contains the following basic housekeeping data:

Latitude, integer 1/10000ths of a degree (4 bytes);

Longitude, integer 1/10000ths of a degree (4 bytes);

GPS time stamp, integer seconds since 0000 01/01/1990 (4 bytes);

The radar's time stamp, integer seconds since 0000 01/01/1990 (4 bytes);

Temperature 1, integer 1/100ths of a degree C (2 bytes);

Temperature 2, integer 1/100ths of a degree C (2 bytes);

Free space available on the master SD card in kB, -1 if card cannot be detected (4 bytes);

Free space available on the secondary SD card in kB, -1 if card cannot be detected (4 bytes);

Battery voltage in integer 1/100ths of a Volt (2 bytes);

50-element histogram from a chirp **using the first pair of attenuator settings** (50 x 1 byte).

The byte order is little-endian.

The message is sent, and any waiting configuration messages that have been sent by the user are uploaded. The radar's present configuration data are overwritten with the new configuration. Although the config.ini file remains unmodified, a new file is created, or over-written if it already exists, called ir_config.ini. This contains the updated configuration information. In the event of a restart, either attended or unattended, the ir_config.ini file, if it exists, will supply the configuration.

To send new configuration information to the radar an email is sent to data@sbd.iridium.com, with the subject containing the radar's Iridium modem IMEI number (eg. 300234010700342). The email message has no body, but contains base-64 format attachment with the new configuration data. The attachment takes the form of a config.ini file, with all the rules associated with config.ini files, plus the additional constraint that it can have a maximum length of 270 bytes. Its content should therefore be limited to the lines in the config file that need to be changed. The extension for the file must be .SBD.

If an Iridium configuration update message is received by the radar, it will, at the end of the SBD exchange, send another message containing the updated configuration. This acts as confirmation that the update has been received and actioned.

Note that setting the Iridium flag to zero will have the effect of permanently disabling communications.

If a sequence of configuration messages have been sent to the radar, these will reside in a queue within the Iridium system. If a message in the queue reaches an age of five days, the system deletes all the queued messages. If the radar is able to contact the system this should never happen. The radar's housekeeping process will continue to read queued messages until the queue is empty. Each configuration message will result in an update to ir_config.ini, and a response SBD message confirming the updated configuration.

The SBD message sent in response to a reconfiguration message has the following format:

NS=30	[Number of SubBursts per burst]
RP=7200	[Repetition Period]
HK=1	[Housekeeping on/off]
MD=10000000	[Maximum file size]
AV=0	[Averaging on/off]
NS=40000	[Number of ADC samples]
GS=1	[GPS clock syncing on/off]
LO=1	[Logging on/off]
GO=0	[GPSOn]
IM=0	[Interval Mode]
SM=0	[Sleep Mode]
WD=3600	[WatchDog timeout]
NA=1	[Number of attenuator settings]
AT=24,20,15,10	[RF attenuator settings]
AF=6,-14,-4,-4	[AF Gain settings]
TR=70.,10.,200.,210.,10.,300.,305.,15.,500.,0.,0.,0	[Triples]
ND=12	[NData]
RO=00000008	[DDS register settings
R1=000C0820	….
R2=0D1F41C8	….

RB=6666666633333333	**….**
RC=000053E3000053E3	**….**
RD=186A186A	**….**
RE=08B5000000000000	**……]**

To test if the Iridium communications are working correctly a Test Iridium button is available on the Housekeeping page when using Attended Mode. Pressing the button results in the radar attempting to send an SBD message to the Iridium system. Text will appear beneath the button giving the result of the test: either a successful transmission, or a failed transmission. If the transmission failed, the radar will have made three attempts. The third possible response is a failure to communicate with the Iridium modem, which implies a hardware failure in the Radar controller (Modem missing, for example). The timeout on each attempt is 20 seconds, so the process can take up to 1 minute. If successful, a message saying "Hello" will have been transferred via the Iridium system.

9.2   Data messages

There are several similarities between the way data uplinks and housekeeping uplinks are handled. The only difference is in the content of the message. The first four fields are the same for both data and housekeeping SBD messages (Latitude, Longitude, GPS time and System time). The remainder of data messages are given over to a maximum of 64 data samples derived from a single averaged burst. The two-way aspects of the housekeeping data exchange applies to data messages also. That is, the radar can be reconfigured after a data uplink in the same way as for after housekeeping. So any reconfiguration messages sent to the radar will be read and enacted either as part of the housekeeping process, or the data uplink, depending on which takes place first. The action of the *GPSSync* parameter also applies to the data message exchange.

The configuration parameter *NData* determines how often a recorded burst is averaged, processed, and the results reported. This happens every *NData* bursts. *NData*=0 or *Iridium*=0 effectively switches off that functionality. Data messages are entirely independent of housekeeping messages, and do not affect the routine collection of data from bursts.

The dataset consists of the bin-offset, amplitude and phase of a series of peaks in the amplitude of the radar return. Each peak is the maximum amplitude found in a predetermined depth interval.

The depth intervals are defined in the configuration file by a series of Matlab-like triples: eg 200:20:600, expressed in the configuration file as 200,10,600, defines a series of 40, 20-m depth intervals between 200 and 600 m. It is important to have an idea of the radar return before attempting to finalise depth intervals. One approach would be to gather a test burst during deployment, and then set the intervals remotely once the test burst had been fully analysed. A typical approach might be to have more intense sampling (smaller depth intervals) in the upper ice column where amplitudes of the internal reflections are higher, rather broader ones at depth, where there might be fewer good reflections, and a more intensive series of intervals covering the basal return. A minimum depth interval of 2 m would be wise. The only benefit to using fewer than the maximum 64 depth intervals is a cost saving in Iridium communications (marginally fewer bytes sent).

The maximum number of triples allowed is 4. Each data sample (data from each 'internal layer', or amplitude peak), takes 5 bytes of message space: two bytes for the peaks depth-bin number, one byte for the absolute value of the amplitude of the peak in dBm, and two bytes for the phase of the peak, in 1/100ths of a degree. All are unsigned integers, stored as little-endians.

Each time a data message is constructed for uptell, it is written to a file that is added to a directory called "SBD" on the primary SD card. The instrument then deletes any files older than MessageTimeout hours from that directory, and attempts to uptell those that remain. The idea is to reduce the chance of a "bad Iridium day" from causing SBD messages to fail to be delivered.

In the sequence of attempts to send messages, if there are ever more than IR_NUM_RETRIES sequential, failed attempts to send a message, then the attempted uptell sequence is aborted.

The longer the timeout period, the larger the list of SBD messages that could build up, especially in the event of a hardware failure on the Iridium communications side (eg damage to the antenna cable). This is therefore a useful function if the instrument is unlikely to be recovered, but should be used with caution if the SBD transfer is just being used to give a flavour of the data, or as a backup in the event of a major problem. Setting the MessageTImeout to zero will disable that functionality, and each message uptell will be attempted only once (but with the usual number of retries (IR_NUM_RETRIES) at that time).

10. More on configuration files

So there are two types of configuration files, one named config.ini, the other ir_config.ini, and there are two possible SD cards, if they are both installed and working. When the system powers up, the Primary slot is checked to see if a working SD card is present. If one is present, that card is checked to see if an ir_config.ini is in the root directory. If so, then that configuration is used for the radar, and the ir_config.ini is copied to the other card, if it is present. If the ir_config.ini is not present, a config.ini is sought on the Primary SD card, and used for the configuration, and again copied to the other card. If a config.ini is not found on the Primary SD card, then the other card is checked, first for an ir_config.ini, and then for a config.ini.

In summary, the order of search for a radar configuration is as follows:

- ir_config.ini on the Primary card (and copied to Secondary card)
- config.ini on the Primary card (and copied to Secondary card)
- ir_config.ini on the Secondary card
- config.ini on the Secondary card.

When a config.ini is uploaded from a connected PC, after being written it is copied to the Secondary card. Similarly, after an ir_config.ini has been created as a result of receiving an Iridium message to update the radar configuration, it is first written to the Primary card, and then copied to the secondary card. NOTE that the ir_config file is generated internally by the radar. It is NOT intended that a user defines the file. In fact, ir_config files should be removed from the SD cards when the system is being left to operate unattended.

11. SAF data processing

The idea of the Store And Forward capability is to reduce the data in volume, and store it on the SD cards. It's then available for download over the Ethernet interface via an FTP server.

If CheckEthernet is set to 5, each burst is averaged and saved to a directory called "SAF" on both SD cards. The data are appended to a file with a time-stamped name, unless the file is larger than a size limit pre-set in the config file, in which case a new file is created. If CheckEthernet is set to 4, the averaged burst is first preprocessed and reduced as follows. The averaged burst, 40,000 samples in length, is zero-padded and rotated, as in Brennan et al. An FFT is then taken, and the complex result trimmed in length and saved as the SAF file. The trimming reduces the length according to that set by maxDepthToGraph in the config file.

If SAF processing has been selected (CheckEthernet is set to 4 or 5), activity on the Ethernet port is checked after each burst. If active, an FTP server is started. The server is terminated if either the port becomes inactive, or the next burst becomes due.

The SAF file structure is very similar to that of the normal data file, except that the header starts with "*** SAF header ***", and a line at the end of the header has been added: "SAFCount=nnnn", where "nnnn" is the number of 4 byte floating point numbers in the SAF data. If CheckEthernet=4,

each consecutive pair of floats is the complex and real components of the result of the FFT. If CheckEthernet=5, SAFCount will be 40,000, and the floats are the burst average values.

12. Batteries and power supply requirements

Instruments with serial number 018 and beyond have a low noise voltage converter card installed in the enclosure. This is to allow efficient operation from a 12V battery. The radar and controller board both require a 6 V supply, and the converter board efficiently (~90+%) steps 12V down to the required voltage. At the same time, the controller monitors the battery voltage via the third "MON" wire. However, also from SN018, a protection diode has been installed that protects the instrument from inadvertent reverse polarity connection to the battery. That diode drops around 0.8 V, further reducing the efficiency, and resulting in the monitored voltage being low by the same amount.

Using a 6V battery will maximise efficiency, but the diode protection would need to be removed and a certain amount of simple rewiring required: the power would need to be wired directly to the two boards, and the MON terminal on the controller (top) board would need to be connected to the adjacent +6V terminal.
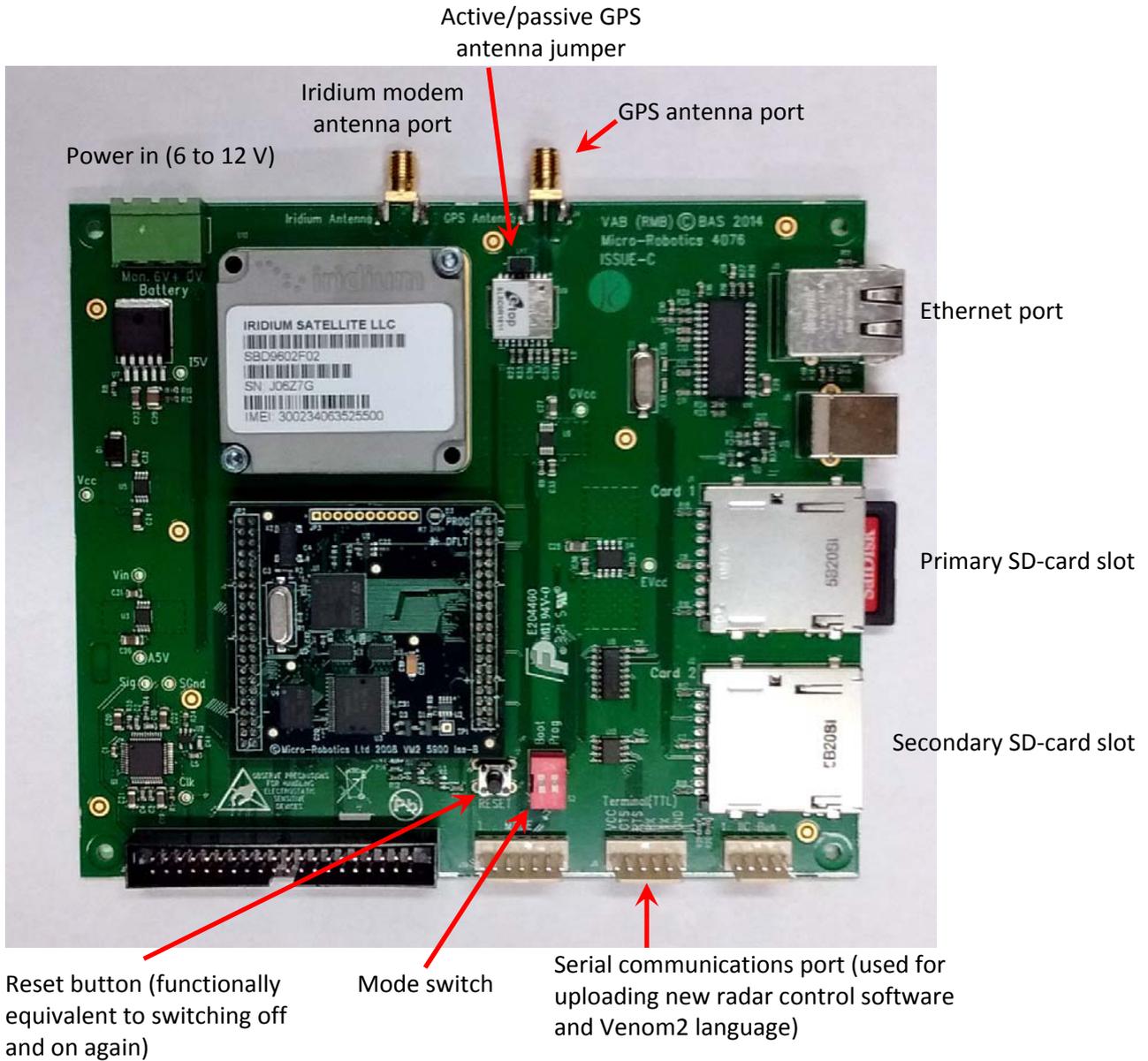
13. Updating the software

It is possible that software updates will need to be installed. This is most easily done by having a copy of the Integrated Development Environment for the controller's programming language (Venom2) installed on a PC, downloadable from the Micro-Robotics website (http://www.microrobotics.co.uk/software/ide.html, and look for VenomIDE). Then updates to the Venom language and the radar control program can be uploaded into the radar using the supplied serial communications lead, RS232 level shifter (small pcb) and null modem. If the PC does not have a serial interface port, and a USB-RS232 converter is to be used instead, it will be important to check to make sure the converter works with the system – different models have different properties.

1. Switch off the instrument.

2. Connect the ribbon-type serial lead to the VAB port. This is the centre connector of the three on the VAB PCB, in line with the 40-way ribbon cable connector. The other end of the cable connects to the small pcb level shifter. It's possible to get the plugs on the end of the ribbon cable the wrong way round. Make sure the Vcc on the level shifter matches the Vcc on the VAB port. Use the null modem to connect to the computer serial port, or serial to USB interface.

3. Slide the mode switch No.2 ("Prog.") to "on".

4. If a new version of the Venom2 language does not need to be loaded, only a new radar control program, jump to step 9.

5. To update the Venom2 language, slide switch No.1 ("Boot") to the "on" position. Load the Venom IDE and adjust the terminal settings, if necessary, to 115 kbaud, hardware handshaking, and make sure it's connected to the correct serial port.

6. Switch the instrument on. Under the File menu, click <Download Venom2 Language>, and browse to and select the .s19 file that contains the updated version of the Venom2 language. It takes a few minutes to download.

7. When completed, slide the Boot switch back to "off" and reset the instrument with the pushbutton.

8. Type Y to clear the memory.

9. To reload the radar control programme (for example, after the Venom2 language has been updated, or if a new version of the radar control program has been issued) click <Open Project...> under the File menu and navigate to the .vpj project file in the directory containing the new program files. The program will then load into the IDE.

10. Make sure the instrument is switched on, with the Prog switch "on", the Boot switch "Off", and the memory cleared. There will be a prompt in the Terminal window to erase the application presently stored in flash memory, to which the answer is Y, and another prompt to erase the memory in RAM, to which the answer is again Y.

11. Under the Edit menu, click <Download All> (or press <F6>), and then wait for the various files to be downloaded and compiled in the controller.

12. Type Protect(1) to copy the new program to flash.

13. Slide the "Prog" switch back to "Off", and switch off the radar.

14. It is important NOT to leave the programming lead connected to the VAB. The reason is that it will drain power from the battery whenever the radar is switched on.

The program has now been updated.

Appendix A. Photograph of controller board (VAB) Issue C

Active/passive GPS
antenna jumper

Iridium modem
antenna port

GPS antenna port

Power in (6 to 12 V)

Ethernet port

Primary SD-card slot

Secondary SD-card slot

Reset button (functionally
equivalent to switching off
and on again)

Mode switch

Serial communications port (used for
uploading new radar control software
and Venom2 language)

Appendix B. Checklist for leaving radar in unattended mode.

Advisable for highlighted lines to be done in advance of the deployment.

1. SD cards formatted as FAT32
2. Master SD card contains a valid config.ini file, and no ir_config.ini files.
3. Sufficient space on SD card(s) for anticipated deployment.
4. Master SD card in primary slot.
5. Secondary card (if used) has no config.ini or ir_config.ini files
6. Secondary card (if used) in secondary slot.
7. No jumper on controller board if passive GPS antenna to be used.
8. Desiccant bag in radar box for long term deployments.
9. All coax connectors on boards (GPS, Iridium, Rx and Tx) are tight.
10. External coax connectors are tight (GPS, Iridium, Rx and Tx)
11. Battery terminals have been tightened.
12. Iridium and GPS antennas fully screwed down on antenna bracket.
13. In Attended Mode:
    a. GPS fix acquired (Housekeeping page)
    b. Iridium test successful (Housekeeping page)
    c. Real time clock set (Housekeeping page)
    d. Test burst made to decide on optimal attenuator settings
    e. Attenuator settings copied to config.ini on card (either by removing card or by using upload on Housekeeping page).
    f. If data uptell to be used, Ndata and Triples determined and copied to config file on card (either by removing card or by using upload on Housekeeping page).
    g. 100-chirp burst captured (Burst page) with optimal attenuator settings for later reassessment of Ndata and Triples settings
    h. Copy taken of the config.ini file left on the instrument.
14. Record made of:
    a. Location;
    b. Instrument serial number;
    c. Time of deployment;
    d. IMEI number of Iridium modem.

Appendix C. Deciding on settings for unattended mode

C.1   What sampling interval to use (RepSecs)

The primary aim of unattended mode is to monitor change. The timescales of the changes of interest dictate the required sampling interval. If, however, there are shorter timescale processes that are likely to cause aliasing, the sampling interval might need to be reduced in order to resolve those faster variations and allow them to be removed. An example I have come across is when trying to monitor ice shelf melt rate variations at time scales of a few days, when there was a strong tidal signal in the ice column's vertical strain and, to a lesser extent, in the melt rate itself. In that case, we used a sampling interval of 2 hours.

C.2   Number of chirps per burst (NSubBursts)

The next decision is about how many chirps need to be recorded in each burst so that enough stacking can be done to improve the signal to noise ratio sufficiently. For most of us, chirps and subbursts are the same thing (provided we use only one attenuator setting – see the manual). This can be a bit tricky to determine ahead of time, and it's quite likely that there won't be time available during the deployment to figure it out from experimentation (pilots like to get away….).

As a guide, anywhere between 20 and 100 chirps seems to work. 100 is (hopefully) more than is required, as it is quite expensive on power and memory. Whatever happens, it is very helpful to get a 100-chirp burst before leaving the site. This can be studied in detail later and, if the Iridium datalink is being used, the number of chirps in a burst can be adjusted. But my first guess would always be about 20.

C.3   Power and memory constraints

Once you have decided how many chirps per burst, then the power and SD card capacity constraints need to be considered. Broadly speaking, each chirp takes about 1 second, at around 0.5 Amps, and takes up 80,000 bytes of storage space. Use the "ApRES Calculator" spreadsheet to get a sense of how much power and SD card capacity will be required. But in general terms, a 16 GB card will allow about 200,000 chirps to be stored, which will cost about 30 Ahr of battery capacity. Taking into consideration the effects of temperature on, say, lead-acid battery chemistry, this means that a 16 GB card is well matched to a 100 Ahr battery. In principle, that should allow a 20-chirp burst every hour for one year.

In reality, the capacity of the battery depends very much on how it's been treated before it gets deployed. A new AGM battery, for example, needs to be cycled a few times before being finally charged. It is safest to install a small (>=15W) solar panel to charge the battery during the summer months, with an appropriate temperature-compensated solar charger sitting beside the battery (eg Genasun). Ensure that the current drawn by the charger is small, otherwise it will significantly add to the load on the battery during the winter (the Genasun product draws about 0.15 ma, contributing less than 1Ahr to the total drain during the winter months.

C.4   Using on-board averaging (Average)

If power is no real issue (plenty of solar charged batteries in the system, for example), then memory will be the limiting factor. By setting Average=1 (or 2) in the config file, only averaged (or stacked) bursts will be stored, and the memory usage will be reduced by factor equal to the number of chirps in a burst. In this way, the problem of memory capacity largely disappears. The downside is that, if a few bad chirps are recorded, they cannot be removed before the averaging takes place on the ApRES. Generally, bad chirps are rare, and when I process the data the first thing I do is to average each burst. However, as the first chirp or two can be a bit anomalous, it is a good idea to set Settle_Cycles=1 or 2 if averaging on the instrument. This is the number of chirps discarded before recording starts for each burst.

C.5 Other factors affecting power usage

The major factor is the amount of time the radar is actually transmitting, as discussed above. Power is also used during the processing needed to create SBD messages, and then the time spent transmitting them. The average current during processing and transmitting is quite low, 0.06 A, but in the event of a poor Iridium link (because of the satellite constellation) the maximum time spent can be two minutes or so, equivalent to 10 or 12 bursts. So, if many SBD messages are to be sent during the day, it is worth considering the consequences for battery usage. Again, this is included in the ApRES Calculator spreadsheet.

Another, more subtle, effect, and one that is not explicitly included in the ApRES Calculator spreadsheet is connected with the file system on the SD cards. When data are written, the file system chains through the files already written until the end is found. That process takes an amount of time that depends on the number of files on the card. It is worth ensuring that the maximum number of files for the full deployment is less than a few thousand, which could mean a delay of up to ten seconds or so. For a full 16 GB card, that would mean setting the maximum file length to 10 to 20 MB.