SCUOLA DI INGEGNERIA AEROSPAZIALE

SAPIENZA UNIVERSITÀ DI ROMA

Astro Bio Cube Satellite Communications

ABCS will be launched soon with the maiden flight of Vega-C by the beginning of July 2022. The satellite orbit will be at 5800 km of altitude with 70° of inclination, which means that ABCS will spend most of the time inside the inner Van Allen Belt, with deadly radiation levels (mostly protons). As a consequence, the expected mission lifetime is pretty short and also error-free operation would be not very likely.

For this reason we are trying to involve as many people as possible to try to receive the signal of ABCS. Astro Bio Cube Satellite operates on the **amateur radio frequencies** in the **UHF** band at the IARU coordinated frequency of 435.600 MHz.

Astro Bio Cube Satellite hosts a ham **digipeater** which is active by default and can be accessed by any radioamateur. Instructions for the use of the digipeater are reported below.

In addition any radio amateur is invited to receive the **satellite telemetry** and share it at his will. Instructions for decoding the telemetry data packets are reported below. Data received by the radio-amateur community around the world will be collected and sorted along with data downloaded by the Ground Station of the School of Aerospace Engineering. All the data will be available for free consultation online and all the contributors will be acknowledged.

Radio link

Radio Frequency Band : UHF

Polarization: circular

Downlink Frequency : 435.600MHz

Uplink Frequency:435.600 MHz

Modulation:9600 baud FSK

Encoding:G3RUH

Protocol:ax.25

Astro Bio Cube Satellite Beacon

Astro Bio Cube Satellite sends periodic beacon messages containing status and telemetry information as well as payload data.

There are three types of beacon messages with the same length of 235 bytes. The three beacons are sent cyclically. The beacon interval is 10s by default but can vary from 5s to 15s according to the satellite operational mode and status.

The beacon type (00, 01, 02) is reported in the tenth byte of the message (after the ax.25 header).

All the beacons contain a common time reference, the current op-mode and the mission phase.

1. Beacon type 00 :Memory and Payload-1

Beacon type 00 contains the information about the status of the on-board computer, the status of the storage and the execution state of the main payload (lab-on-chip) experiments.

The last part of the beacon contains a data packet (first half) of the executed lab-on-chip experiments.

Bytes	Index	Size	ID	Type
0-2	0	3	Beacon Header	ascii
3-4	3	2	Radio Index	uint16
5-6	5	2	Radio Ack Index	uint16
7	7	1	Type	uint8
8	8	1	Size	uint8
9	9	1	Sub-type	uint8
10-13	10	4	Total Mission Minutes	uint32
14	14	1	Status (Op Mode)	uint8
15	15	1	Mission Phase	uint8
16-19	16	4	Last Mission Phase Minute Ref	uint32
20	20	1	Memory Boot Type	uint8
21-22	21	2	Reboots Counter	uint16
23	23	1	Do not Init Memory	uint8
24	24	1	Bus and Sensors Status	uint8
25	25	1	Debug Is On	uint8
26	26	1	Ignore CRC	uint8
27-30	27	4	Internal RTC	uint32

31-34	31	4	Time at Boot	uint32
35	35	1	PL1 Exp Protocol Setup	uint8
36	36	1	PL1 Exp Boot Type	uint8
37	37	1	PL1 Experiment Running	uint8
38	38	1	PL1 Exp Status and Mode	uint8
39	39	1	PL1 Current Experiment	uint8
40	40	1	PL1 Current Step	uint8
41-44	41	4	PL1 Elapsed Time in Step	uint32
45	45	1	PL1 Status Parallel	uint8
46	46	1	PL1 Sub Status Parallel	uint8
47	47	1	PL1 Sub Status Value	uint8
48-51	48	4	PL1 Labonchip Status Address	hex
52-55	52	4	PL1 Exp Protocol Address 1	hex
56-59	56	4	PL1 Exp Protocol Address 2	hex
60-63	60	4	PL1 Exp Protocol Address 3	hex
64-67	64	4	PL1 Exp Protocol Address 4	hex
68-71	68	4	PL1 Exp Protocol Address 5	hex
72-75	72	4	PL1 Exp Protocol Address 6	hex
76-77	76	2	Memory Errors	uint16
78-81	78	4	Memory Event Start Free Address	hex
82-85	82	4	Memory Event End Free Address	hex
86-89	86	4	Memory Sensors Start Free Address	hex
90-93	90	4	Memory Sensors End Free Address	hex
94-97	94	4	Memory Marie Start Free Address	hex
98-101	98	4	Memory Marie End Free Address	hex
102-105	102	4	PL1 Last Beacon Address	hex
106-233	106	128	PL1 Experiment Data (live or past)	NA
234	234	1	CRC	uint32
Total size:	**235**			

2. Beacon type 01: Sensors

Beacon type 01 contains most of the sensors' telemetry and the information about the power system. The last part of the beacon contains a data packet (second half) of lab-on-chip experiments.

Bytes	Index	Size	ID	Type
0-2	0	3	Beacon Header	ascii
3-4	3	2	Radio Index	uint16
5-6	5	2	Radio Ack Index	uint16
7	7	1	Type	uint8
8	8	1	Size	uint8
9	9	1	Sub-type	uint8
10-13	10	4	Total Mission Minutes	uint32
14	14	1	Status (Op Mode)	uint8
15	15	1	Mission Phase	uint8
16-19	16	4	Time Now	uint32
20-23	20	4	External RTC	uint32
24	24	1	Watchdog Interval	hex
25-28	25	4	Last Update External RTC UnixTime	uint32
29-32	29	4	Radio Last Time Rx Ground	uint32
33-34	33	2	Radio Ack Packet Index	uint16
35	35	1	Radio Temperature	uint8
36	36	1	Radio RSSI	uint8
37	37	1	Radio Amateur On (HAM)	uint8
38	38	1	Temperature MCU	int8
39	39	1	Temperature MCU Max	uint8
40	40	1	Temperature MCU Min	int8
41	41	1	Temperature FPGA	int8
42	42	1	Temperature FPGA Max	int8
43	43	1	Temperature FPGA Min	int8
44-45	44	2	Temperature Additional Data	hex
46-47	46	2	Magnetometer X	int16
48-49	48	2	Magnetometer Y	int16
50-51	50	2	Magnetometer Z	int16
52-53	52	2	Gyroscope X	int16
54-55	54	2	Gyroscope Y	int16

56-57	56	2	Gyroscope Z	int16
58-59	58	2	Abacus Current	uint16
60-61	60	2	Abacus Current Max	int16
62-63	62	2	Abacus Current Min	int16
64-65	64	2	Abacus Current Avg	uint16
66-67	66	2	EPS Battery Voltage	uint16
68-69	68	2	EPS Battery Discharge Current	uint16
70	70	1	EPS Battery Temperture	uint8
71	71	1	EPS PBus Current	uint8
72	72	1	PL1 Current Experiment	uint8
73	73	1	PL1 Current Step	uint8
74	74	1	Kayser I2C Bus	uint8
75	75	1	Kayser Sensor Status Bus 0	uint8
76	76	1	Kayser Sensor Status Bus 1	uint8
77	77	1	Kayser RadFET LED EN	uint8
78	78	1	Kayser Wet Sensor EN Sel	uint8
79	79	1	Kayser Pump EN	uint8
80-81	80	2	Wet Sensor 1	uint16
82-83	82	2	Wet Sensor 2	uint16
84	84	1	Kayser Temperature 1	int8
85	85	1	Kayser Temperature 2	int8
86	86	1	Kayser Temperature Max	int8
87	87	1	Kayser Temperature Min	int8
88-89	88	2	Kayser Pressure	uint16
90-91	90	2	Kayser Pressure Max	uint16
92-93	92	2	Kayser Pressure Min	uint16
94	94	1	Kayser Pressure Status	hex
95	95	1	Kayser Pressure Temperature	uint8
96-97	96	2	Kayser Luminosity	uint16
98-99	98	2	Kayser RadFET 1	uint16
100-101	100	2	Kayser RadFET 2	uint16
102-105	102	4	PL1 Last Beacon Address	hex
106-233	106	128	PL1 Experiment Data (live or past)	NA
234	234	1	CRC	uint32
Total size:	**235**			

3. Beacon type 02 :Electric Power system and Payload -2

Beacon type 02 contains detailed information about the on board power system and radioamateur data. The last part of the beacon contains a data packet of the secondary payload experiments.

Bytes	Index	Size	ID	Type
0-2	0	3	Beacon Header	ascii
3-4	3	2	Radio Index	uint16
5-6	5	2	Radio Ack Index	uint16
7	7	1	Type	uint8
8	8	1	Size	uint8
9	9	1	Sub-type	uint8
10-13	10	4	Total Mission Minutes	uint32
14	14	1	Status (Op Mode)	uint8
15	15	1	Mission Phase	uint8
16-19	16	4	Time Now	uint32
20-21	20	2	EPS Battery Voltage	uint16
22-23	22	2	EPS Battery Voltage Max	uint16
24-25	24	2	EPS Battery Voltage Min	uint16
26-27	26	2	EPS Battery Discharge Current	uint16
28-29	28	2	EPS Battery Discharge Current Max	uint16
30-31	30	2	EPS Battery Discharge Current Min	uint16
32	32	1	EPS Battery Charge Current	uint8
33	33	1	EPS Battery Charge Current Max	uint8
34	34	1	EPS Battery Charge Current Min	uint8
35	35	1	EPS Battery Temperture	uint8
36	36	1	EPS Battery Temperture Max	uint8
37	37	1	EPS Battery Temperture Min	uint8
38	38	1	EPS PV0 Current	uint8
39	39	1	EPS PV0 Current Max	uint8
40	40	1	EPS PV0 Current Min	uint8
41	41	1	EPS PV1 Current	uint8
42	42	1	EPS PV1 Current Max	uint8
43	43	1	EPS PV1 Current Min	uint8

44	44	1	EPS 3v3 Current	uint8
45	45	1	EPS 3v3 Current Max	uint8
46	46	1	EPS 3v3 Current Min	uint8
47	47	1	EPS 5v Current	uint8
48	48	1	EPS 5v Current Max	uint8
49	49	1	EPS 5v Current Min	uint8
50	50	1	EPS PBus Current	uint8
51	51	1	EPS PBus Current Max	uint8
52	52	1	EPS PBus Current Min	uint8
53	53	1	EPS Active Sensors	uint16
54-57	54	4	PL2 Start Free Address	hex
58-61	58	4	PL2 End Free Address	hex
62-63	62	2	PL2 Active Flag and STATUS	uint16
64-65	64	2	PL2 MCU Protected Counts	uint16
66-67	66	2	PL2 MCU External Counts	uint16
68-69	68	2	PL2 IMU Protected Counts	uint16
70-71	70	2	PL2 IMU Protected Interval	uint16
72-73	72	2	PL2 IMU External Counts	uint16
74-75	74	2	PL2 IMU External Interval	uint16
76-77	76	2	Amature packets	hex
78-79	78	2	Amature Tx Packets	hex
80-83	80	4	Last time Radio HAM RX	hex
84-87	84	4	Last time Radio HAM TX	hex
88-99	88	12	Radio HAM Call SIgn	hex
100-101	100	2	Event Counter	uint16
102-105	102	4	PL2 Last Beacon Address	hex
106-233	106	128	PL2 Experiment Data	NA
234	234	1	CRC	uint32
Total size:	**235**			

Astro Bio Cube Satellite Digipeater

The satellite will reply to an incoming radioamateur packet by resending it to ground.

The last callsign of the last radioamateur that contacted the satellite is reported in the beacon message of the satellite (type 02).

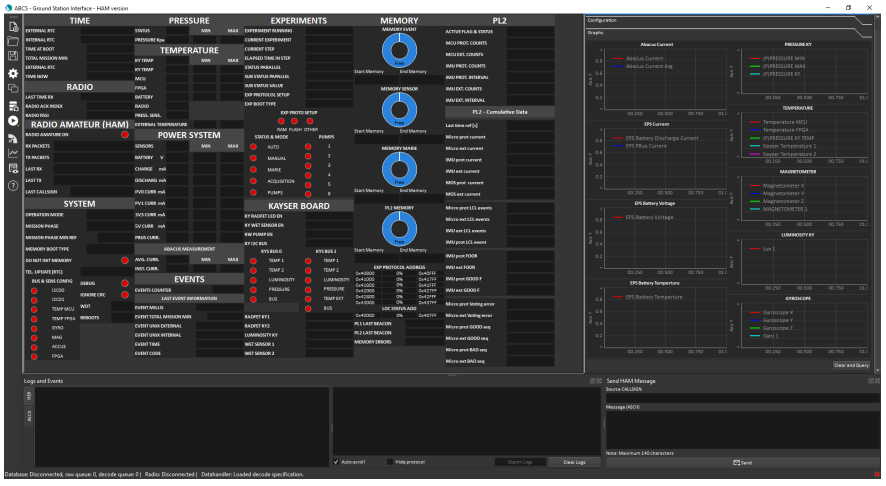
Using the digipeater is extremely simple: To use the digipeater one just needs to send a valid ax.25 data packet starting with the keyword “HAM” followed by the message.

Example: HAMHello world!!!

ABCS will transmit: CQHello world!!!

The message length is limited to 140 characters to avoid overloading the satellite radio and cope with the limited power budget. For the same reason, a dead time of about 10 seconds is then applied before the next digipeater action is enabled. However, any contact in this time window will be counted and the callsign stored onboard and reported in the beacon.

Astro Bio Cube Satellite Graphical User Interface

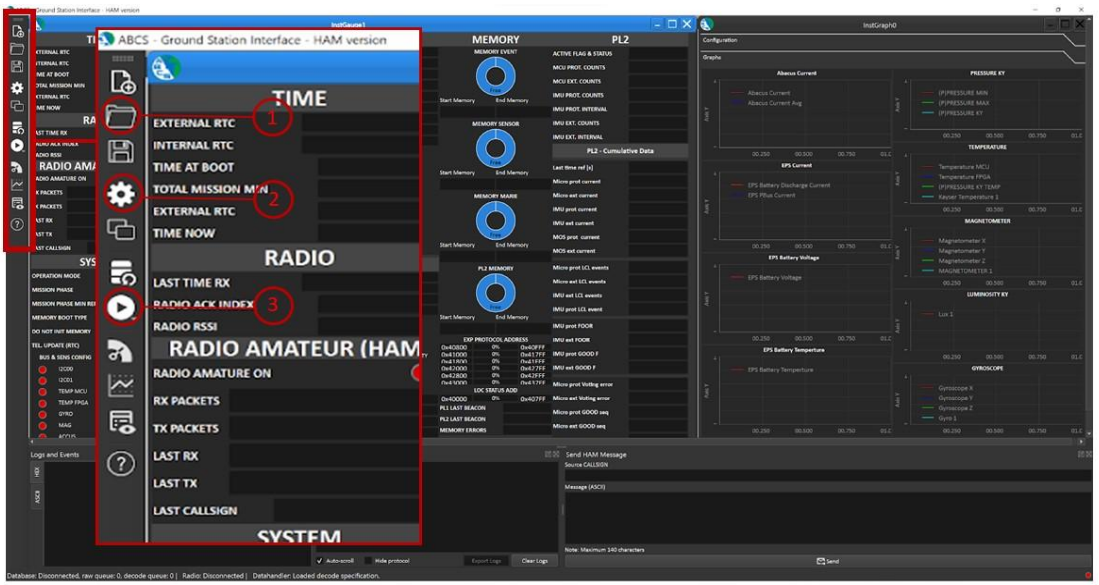


The ABCS GUI allows to decode the demodulated packages and display relevant telemetry information in real-time. In addition it allows to easily access the radioham digipeater.

The software can be interfaced with the radio/TNC hardware as well as to other softwares (gnuradio, HS_Soundmodem,...) using both serial and TCP interfaces.

The ABCS GUI runs under Windows (tested on Windows 7, Windows 10, Windows 11) and under Linux using Wine (tested on Ubuntu 20.4 LTS).

Overview of the GUI



The GUI contains 4 main areas:

a. The values and widget area where the decoded beacon data are reported. Three beacons (one per each beacon type) are needed to display all the data
b. A graphs window where relevant information are plotted over time as soon as more data is available
c. Raw data and event messages window
d. Digipeater window

The zoomed area shows:

1. Folder icon to load the workspace
2. Setting icon to select the radio input
3. Start / stop button

Initial Set-up

Steps to be followed when running the GUI for the first time. Note that there are two different inputs available in the GUI: user needs to select one the two inputs (Serial/TCP) and enter the right parameters in the settings and save it.

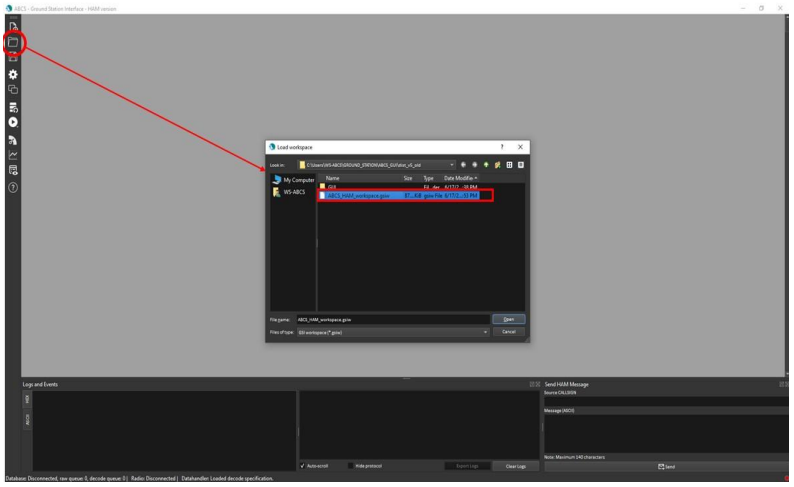
Step 1: load the workspace file

Step 2: configure the connection between the radio and the GUI

Step 3: open the connection and enjoy.

STEP 1 : Load The Workspace File

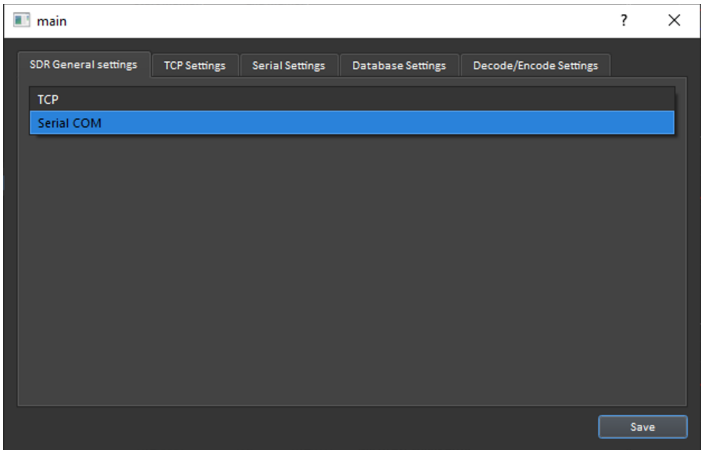
Initially the user needs to open the file “ABCS_HAM_workspace.gsiw” as shown in the image below. This file contains the various fields used to display the decode data.



Loading the workspace for the first time

STEP 2: Connect the Radio/TNC/SDR

1. Settings can be opened by clicking the settings icon ⚙ in the left side ribbon. Settings icon is disabled when the GUI is running.
2. In the connection mode there are two different types of connection that can be selected. Users can use either Serial Com or TCP according to their Radio connection.



General settings tab

STEP 2.a : Serial Connection Settings

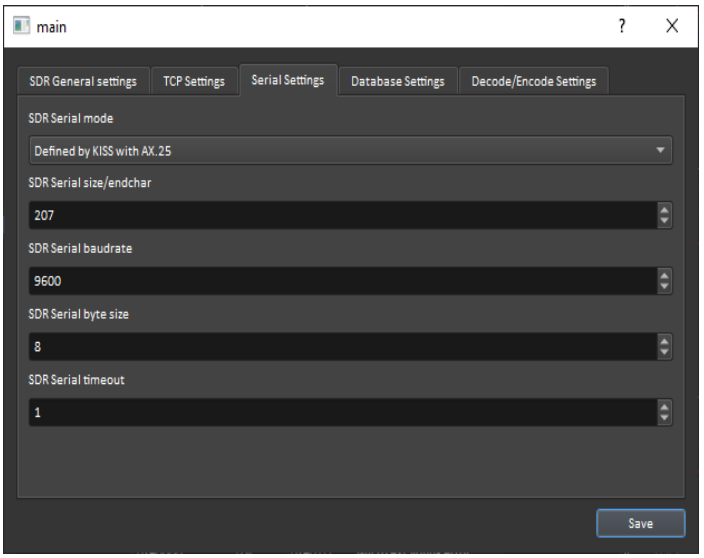
Open the serial connection tab.

The various fields in the Serial Settings tab need to be verified to match the user's hardware. This is the most common configuration when using a TNC: in this case both normal TNC operation and KISS mode are supported, selecting the appropriate configuration in the Serial Mode drop down menu.

In KISS mode, the AX25 header is processed by the GUI and data are extracted from the packet payload. Without KISS mode, only the AX.25 payload data must be passed to the GUI discarding the AX25 header before doing that.

Please note that the serial baud rate refers to the connection with the Radio/TNC which may differ from the RF baud rate of 9600 baud.

Hit save when the configuration has been selected.



Serial settings tab

STEP 2.b : TCP Connection Settings

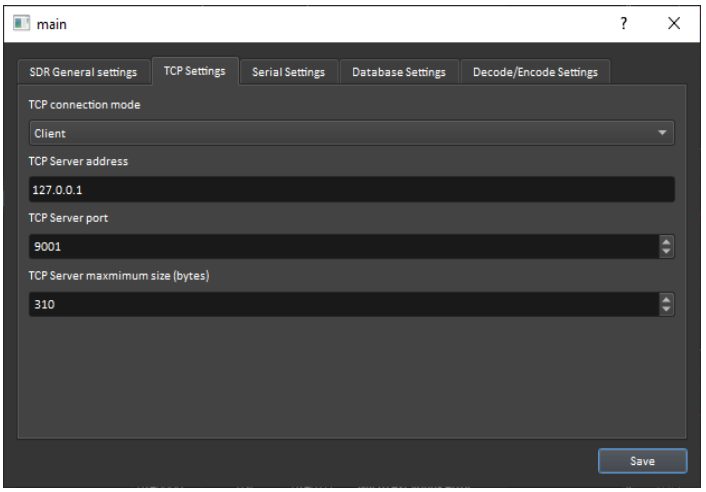
This configuration can be adopted when using an SDR and a gnuradio flowgraph for demodulating the message or similarly if SDR, SDR software (SDR Console, SDR#, HDSDR) and a sound modem (HS_Soundmodem) are used.

The following are the various fields available in TCP Settings.

a. TCP Server address
b. TCP Server port

c. TCP Server maximum size (bytes)

Hit save when the configuration has been selected.



TCP Settings tab

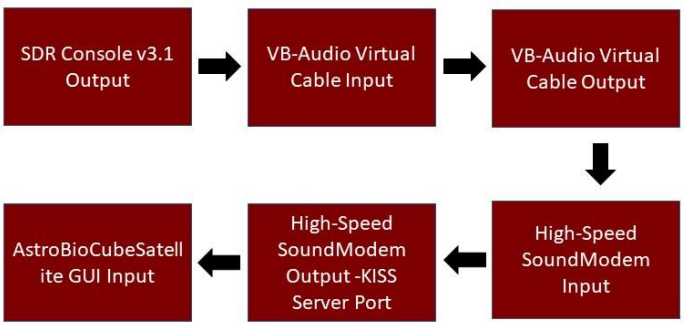
STEP 3 : Start the ABCS GUI

The user needs to click on the START/STOP button to open the connection to the radio using the configuration stored in the settings.

Please note that the selection of the serial COM port is done here: the list of the available COM ports appears close to the START button when clicking it, allowing to select the desired one.

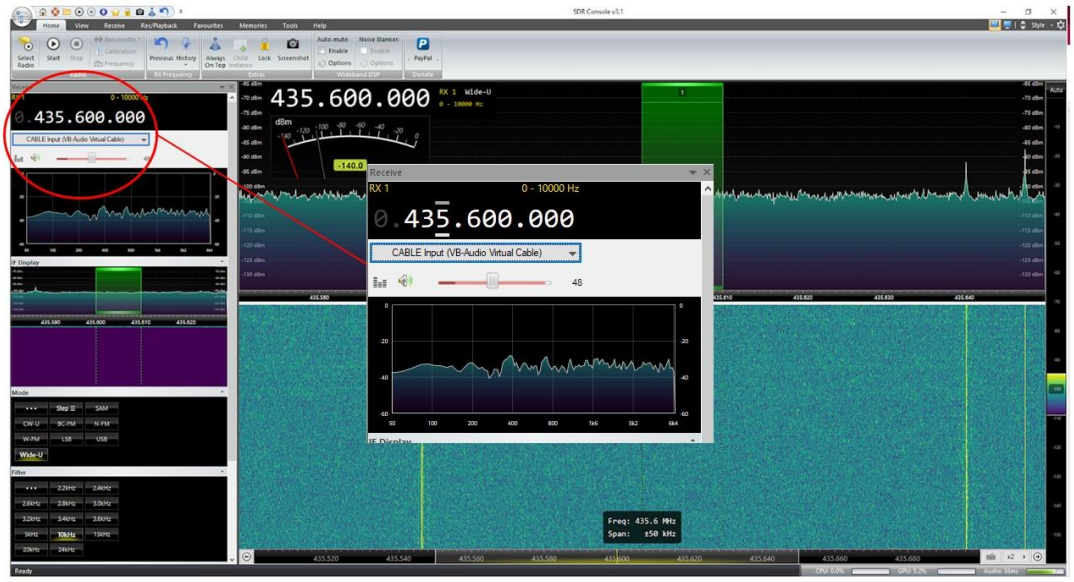
Example: Using ABCS GUI with a SDR setup

In this section a practical usage example is reported using a SDR and conventional freeware software.



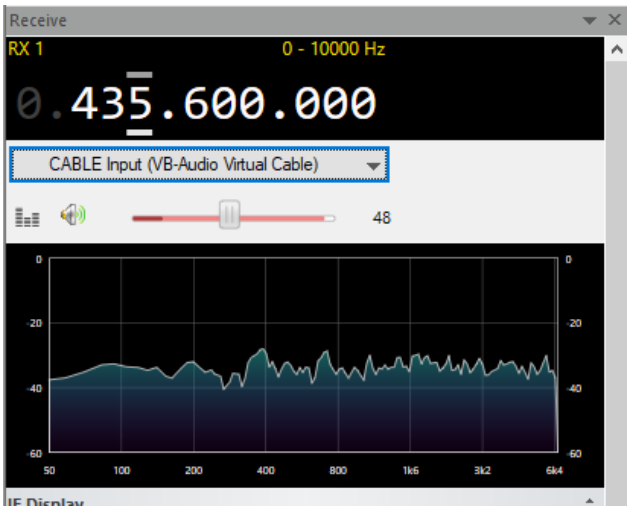
1) SDR CONSOLE Output Settings

SDR Console is a free Software Defined Radio Based software used to tune, perform doppler correction, receive the signal and demodulate the satellite signal.



SDR Console

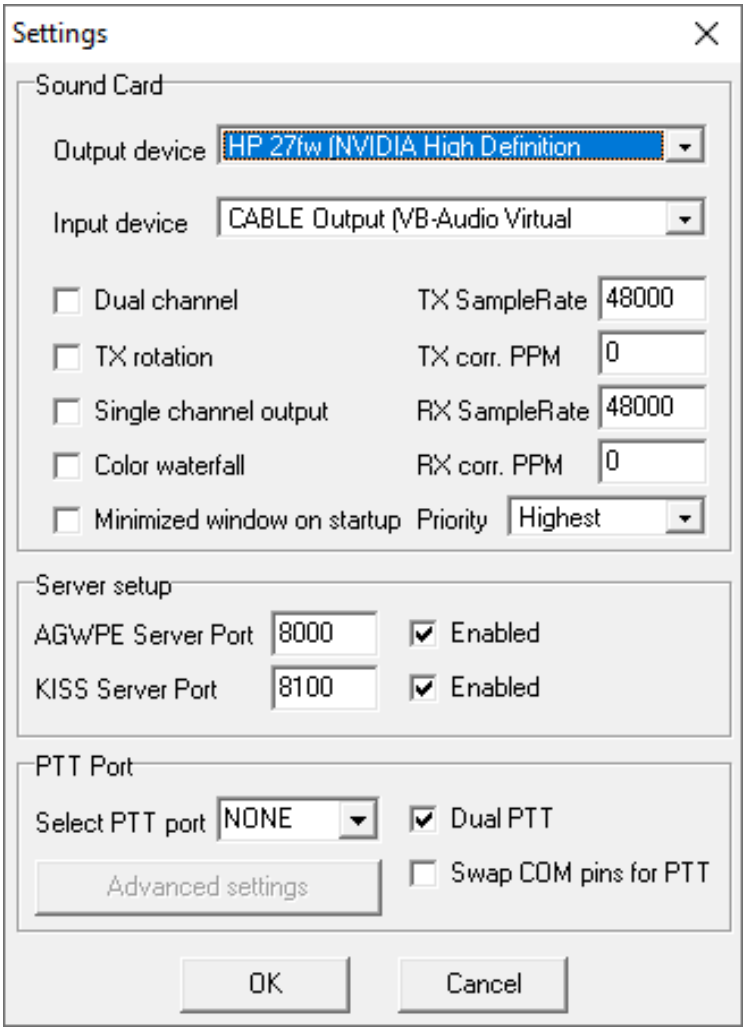
Virtual Audio Cable is a software which creates a virtual audio cable that is used here to connect the output of the SDR Console to the Input of High Speed sound modem. VB-Cable software needs to be installed and the link to download the software can be found in the last page of this document



SDR Console Output Setting

2) High Speed Sound Modem Settings

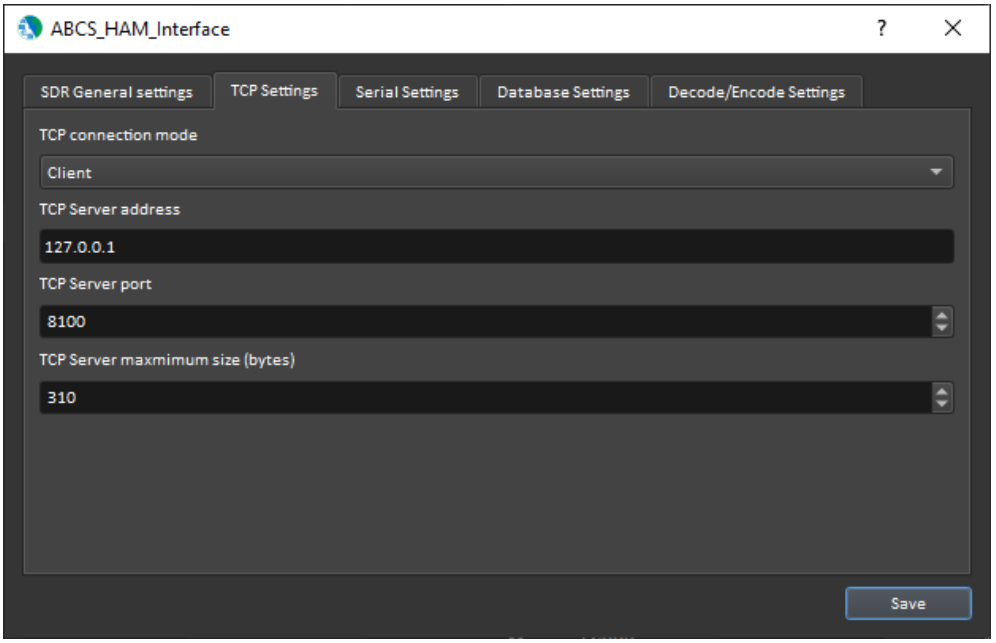
1. In the input device drop down select “CABLE Output (VB_Audio Virtual
2. High speed sound modem is used to decode ax.25 Packets and pass them in KISS mode to the AstroBio CubeSatellite GUI
3. The connection from the HS_Sound Modem is done through TCP Server which needs to be enabled as show in the above image



Setting Tab in the High speed sound modem

3) TCP Settings in ABCS GUI

In the TCP settings window configure the client by using the conventional localhost address (127.0.0.1) and the same port number selected in the HS_Soundmodem KISS output configuration.



TCP Settings on the AstroBioCubeSatellite GUI

Useful Links

1. SDR Console v3.1
2. VB-audio cable Downloads
3. High-Speed Sound Modem
4. AstroBioCubeSatellite Graphical User Interface
5. School of Aerospace Engineering Sapienza University