

AFE822x SDR-Net protocol extensions

This document contains information that can help to add Dual channel AFE822x SDR-Net support for SDR application that has already support of single channel AFEDRI SDR-Net.

1. Some important difference between AFE822x SDR and AFEDRI SDR:

- All information provided for *AFE822x SDR* is applied also to *AFEDRI SDR-Net x2* model
- Optional AFE822x SDR-Net can send the new ID string “AFE822x SDR-Net”
- AFE822x SDR does not have “FE Gain” control, so this command should not be used or should be set to 1.
- AFE822x SDR has two internal DDC receivers (channels), that can be used separately or simultaneously.
- AFE822x SDR has optional embedded AGC control, that allows automatically control “RF Gain” settings to prevent ADC overload.

2. The new modes supported by AFE822x SDR-Net

The AFE822x SDR has the next modes:

- Single channel mode
- Diversity (dual channel) mode
- Dual Channel mode
- Diversity (single channel) mode
- Multistream mode

Below is the short description for each mode:

a. Single channel mode

This mode is fully equivalent to AFEDRI SDR-Net standard mode, i.e. control protocol and data stream structure in USB and Network mode are same for AFE822x SDR and AFEDRI SDR.

The maximal sample rate is up to 2000kHz.

The only difference that for AFE822x SDR user can choose which (of two available) channel to use for reception (like antenna switch).

b. Diversity (dual channel) mode

In this mode both SDR channels are working synchronously i.e. both always tuned to the same frequency and have the same sample rate and the same RF Gain, providing two coherent receivers.

The phase shift between coherent channel can be hardware controlled.

In this mode when user is changing central (NCO) frequency, SDR will make resynchronisation sequence - that is audible as some gap (spike) in decoded signal.

Control protocol in Diversity (dual channel) mode mostly compatible with AFEDRI SDR, but has some difference (will be described below)

The IQ data stream in USB Audio connection is equivalent to 4 channel audio device (or 2 stereo channels)

The data stream in network connection has similar packet structure, headers and size as for single channel mode, but contains multiplexed IQ data for both channels going sequentially.

The maximal sample rate for Diversity (dual channel mode) is limited to 1000kHz (half of single channel mode maximum)

c. Dual Channel mode

In this mode SDR represents two independent receiver each channel can be tuned independently to it's own central frequency and have independent RF Gain settings, only one parameters always kept the same - is sample rate.

The IQ data stream in USB audio and networked connection has the same structure as for Diversity (Dual Channel) - see description above.

The maximal sample rate for Dual channel mode is limited to 1000kHz (half of single channel mode maximum).

d. Diversity (single channel mode)

In this mode both SDR channels are working synchronously i.e. both always tuned to the same frequency and have the same sample rate and the same RF Gain, providing two coherent receivers.

The phase shift between coherent channel can be hardware controlled.

In this mode when user is changing central (NCO) frequency, SDR will make resynchronisation sequence - that is audible as some gap (spike) in decoded signal.

Control protocol in Diversity (dual channel) mode mostly compatible with AFEDRI SDR, but has some difference (will be described below).

The IQ data stream in USB Audio connection is equivalent to 2 channel audio device (or single stereo channel) - it is same as for Single channel mode, the

only difference that IQ data stream is formed as sum of signals from two coherent channels.

The data stream in network connection is similar to single channel mode, but IQ data stream is formed as sum of signals from two coherent channels.

The maximal sample rate for Diversity (dual channel mode) is limited in some AFE822x SDR revision to 1000kHz and some can provide 2000kHz maximum.

Diversity (single channel) mode was implemented for compatibility purposes and can be ignored in SDR applications (in SDR-Radio for example) - because can be implemented better way using digital signal processing on PC.

2. Software Control interface

As example of control API, the source code for command line SDR control utility [sdr_commander.v23](#) and [SDR_Network_Control_Box](#) have been used.

2.1. SDR modes definitions (header file: multichannel_modes.h):

```
#define DUAL_CHANNEL_MODE_OFF 0  
#define DIVERSITY_MODE 1  
#define DUAL_CHANNEL_MODE 2  
#define DIVERSITY_INTERNAL_ADD_MODE 3  
#define QUAD_DIVERSITY_MODE 4 /* Used only for Quad channel SDR  
*/  
  
#define QUAD_CHANNEL_MODE 5 /* Used only for Quad channel SDR */
```

2.2. DDC channels numeration definitions (header file from SDR_Network_Control_Box sources: channels.h)

```
#define AFE_INTERFACE_1 0 /* DDC 1 */  
#define AFE_INTERFACE_2 2 /* DDC 2 */  
#define AFE_INTERFACE_3 3 /* Used only for Quad channel SDR */  
#define AFE_INTERFACE_4 4 /* Used only for Quad channel SDR */
```

3. AFE822x SDR USB HID commands list

Below are listed USB HID commands, that specific for AFE822x SDR

I. List of the commands that have to be implemented for AFE822x support

Set Multichannel mode command

Command	HID report ID	HID command	Mode	Channel number	Reserved	Reserved	Reserved
PC -> SDR	0x02	48	0x00	0x02	0x00	0x00	0x00
SDR's Respond	HID report ID	ACK	HID command	Reserved	Reserved	Reserved	Reserved
SDR -> PC	0x06	28	48	0x00	0x00	0x00	0x00
Example description	This command sets SDR to Single channel mode (0x00) , RX channel (antenna) number will be - DDC 2						

- Mode - should be the value listed in definitions above
- Channel number - for Single channel mode, should be the value listed in definitions above, for any other modes should be set to 0x00 (zero)
- Reserved value should be set to 0x00.

Set central (NCO) frequency command

Command	HID report ID	LSB of Frequency value (Hz)	Frequency value (Hz)	Frequency value (Hz)	MSB of Frequency value (Hz)	Channel number	Reserved
PC -> SDR	0x03	0x10	0x93	0x6B	0x00	0x02	0x00
SDR's Respond	HID report ID	ACK	HID command	Reserved	Reserved	Reserved	Reserved
SDR -> PC	0x06	28	3	0x00	0x00	0x00	0x00
Example description	This command sets central (NCO) frequency value to 7050000 Hz i.e. 0x006B9310 for RX channel's 2 (0x02)						

- Frequency value in Hertz units in less significant order (LSB first)
- Channel number - for Single channel and all Diversity modes, should be 0x00, for Dual channel mode you should be set to desired DDC (channel) number, where you want to change frequency
- Reserved value should be set to 0x00.

Set RF Gain command

Command	HID report ID	HID command	RF gain value	Channel number	Reserved	Reserved	Reserved
PC -> SDR	0x02	8	0x64	0x00	0x00	0x00	0x00
SDR's Respond	HID report ID	ACK	HID command	Reserved	Reserved	Reserved	Reserved
SDR -> PC	0x06	28	8	0x00	0x00	0x00	0x00
Example description	This command sets RF Gain to +14dB (0x64) for RX channel's 1 (0x00)						

- RF Gain value - calculated in same manner as for AFEDRI SDR
- Channel number - for Single channel and all Diversity modes, should be 0x00, for Dual channel mode you should use desired DDC (channel) number
- Reserved value should be set to 0x00.

Set FE Gain command

Command	HID report ID	HID command	RF gain value	Channel number	Reserved	Reserved	Reserved
PC -> SDR	0x02	2	0x00	0x00	0x00	0x00	0x00
SDR's Respond	HID report ID	ACK	HID command	Reserved	Reserved	Reserved	Reserved
SDR -> PC	0x06	28	2	0x00	0x00	0x00	0x00
Example description	This command sets FE Gain to 0x00 for RX channel 1 (0x00) , for AFE822x SDR FE Gain parameter should be always 0x00						

- FE Gain value - for AFE822x SDR should be always 0x00
- Channel number - for AFE822x SDR, should be 0x00
- Reserved value should be set to 0x00.

Get SDR ID index command (this command can be used as replacement of TCP - SDR Name command)

Command	HID report ID	HID command	Reserved	Reserved	Reserved	Reserved	Reserved
PC -> SDR	0x02	51	0x00	0x00	0x00	0x00	0x00
SDR's Respond	HID report ID	HID command	SDR (AFEDRI) ID index	Reserved	Reserved	Reserved	Reserved
SDR -> PC	0x06	51	0x00	0x00	0x00	0x00	0x00
Example description	This command requests SDR ID index, respond contains unsigned 8 bit index number						

- Respond contains SDR ID index, that is 8-bit unsigned number, can have the next values:

SDR ID index	related string name (transferred over TCP protocol)
0	“AFEDRI SDR-Net”
1	“SDR-IP”
2	“AFE822x SDR-Net”

II. Commands list that are optional for AFE822x SDR support

Set Phase shift command

Command	HID report ID	HID command	Phase (LSB)	Phase (MSB)	Channel number	Reserved	Reserved
PC -> SDR	0x02	56	0x40	0x0B	0x02	0x00	0x00
SDR's Respond	HID report ID	ACK	HID command	Reserved	Reserved	Reserved	Reserved
SDR -> PC	0x06	28	56	0x00	0x00	0x00	0x00
Example description	This command sets phase shift to 0x0B40 -> 180 deg. for RX channel 2 (0x02)						

- Phase shift value, for desired channel, it has 16-bit size in less significant order this value is set in degrees multiplied to 16, so it has minimum 0 maximum 5760 that corresponds to 360 degrees (i.e. phase angle resolution 1/16 degree), this parameter is used only in Diversity modes
- Channel number - set phase for defined DDC (channel)
- Reserved value should be set to 0x00.
- Phase shift control can be ignored in application (for example SDR-Radio) and alternatively implemented in digital signal processing procedures if needed.

Get AGC state command

Command	HID report ID	HID command	Reserved	Reserved	Reserved	Reserved	Reserved
PC -> SDR	0x02	71	0x00	0x00	0x00	0x00	0x00
SDR's Respond	HID report ID	HID command	AGC state	Reserved	Reserved	Reserved	Reserved
SDR -> PC	0x06	71	0x03	0x00	0x00	0x00	0x00
Example description	This command requests current DDC AGC state, respond shows that both DDC1 and DDC2 have AGC enabled						

- Request AGC state
- Respond contains bit mask where “1” - means AGC for specific DDC enabled, “0” means - AGC disables (this mode equivalent to AFEDRI SDR). Bit make has next structure:

AGC state response structure

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Reserved	Reserved	Reserved	Reserved	DDC 4 AGC state	DDC 3 AGC state	DDC 2 AGC state	DDC 1 AGC state

- Reserved value should be set to 0x00.
- DDC 4 and DDC 3 is actual for Quad Channel SDR only
- AGC - is optional feature, SDR application can ignore AGC support for AFE822x

Set AGC (overload) mode command

Command	HID report ID	HID command	AGC state mask	Reserved	Reserved	Reserved	Reserved
PC -> SDR	0x02	69	0x03	0x00	0x00	0x00	0x00
SDR's Respond	HID report ID	ACK	HID command	Reserved	Reserved	Reserved	Reserved
SDR -> PC	0x06	28	69	0x00	0x00	0x00	0x00
Example description	This command enables/disables AGC (ADC overload protection) mode, the AGC state mask similar to Get AGC state command						

- AGC state mask , similar to mask described for Get AGC state command, where “1” - means AGC for specific DDC enabled, “0” means - AGC disables (this mode equivalent to AFEDRI SDR). Bit make structure also the same.

III. Networked TCP protocol (HID protocol over TCP forward)

Despite AFE822x SDR-Net supports SDR-IP protocol and backward compatible with AFEDRI SDR-Net.

As sequence , AFE822x SDR (like AFEDRI SDR) supports USB HID command protocol forward over TCP connection, so all USB HID commands can be used over network Tcp connection. To provide HID protocol over TCP forward - the two additional header bytes , for reference please check the table below (example - Set Multichannel mode command):

Set Multichannel mode command (TCP forward)

Command	Network TCP header		Standard USB HID packet						
	TCP header LSB	TCP header MSB	HID report ID	HID command	Mode	Channel number	Reserved	Reserved	Reserved
PC -> SDR	0x09	0xE0	0x02	48	0x00	0x02	0x00	0x00	0x00
SDR's Respond	TCP header LSB	TCP header MSB	HID report ID	ACK	HID command	Reserved	Reserved	Reserved	Reserved
SDR -> PC	0x09	0xE0	0x06	28	48	0x00	0x00	0x00	0x00
Example description	This command sets SDR to Single channel mode (0x00) , RX channel (antenna) number will be - DDC 2								

Some commands (for example set central frequency, RF gain) in native SDR-IP protocol and USB HID do the same thing, user can use any variant he likes.

IV. Networked TCP protocol (AFEDRI SDR-Net / SDR-IP compatibility)

AFE822x SDR-Net backward compatible with AFEDRI SDR-Net. There is some some small difference between AFEDRI SDR TCP commands and AFE822x SDR_Net, channel number parameter (that is always set to 0 for AFEDRI SDR-Net) should be set to correct channel number (channel numbering is defined above in this document), when SDR used in any Dual channel mode (Diversity , Dual Channel modes). All other command parameters are same as for AFEDRI SDR-Net. Below, in the table, cells coloured in orange shows the new (relatively to AFEDRI SDR-Net) parameter (channel number). Channel number is defined in this document above.

Set central (NCO) frequency (SDR-IP, TCP command)

Command	SDR-IP header LSB	SDR-IP header MSB	Control Item code LSB	Control Item code MSB	Channel number	NCO Frequency				
						byte 0 (LSB)	byte 1	byte 2	byte 3	byte 5 (MSB)
PC -> SDR	0x0A	0x00	0x20	0x00	0x02	0x10	0x93	0x6B	0x00	0x00
SDR's Respond	SDR-IP header LSB	SDR-IP header MSB	Control Item code LSB	Control Item code MSB	Channel number	NCO Frequency				
						byte 0 (LSB)	byte 1	byte 2	byte 3	byte 5 (MSB)
SDR -> PC	0x0A	0x00	0x20	0x00	0x02	0x10	0x93	0x6B	0x00	0x00
Example description	This command sets central (NCO) frequency value to 7050000 Hz i.e. 0x006B9310 for RX channel's 2 (0x02)									

Set RF Gain command (SDR-IP, TCP command)

Command	SDR-IP header LSB	SDR-IP header MSB	Control Item code LSB	Control Item code MSB	Channel number	RF gain value (signed char)
PC -> SDR	0x06	0x00	0x38	0x00	0x02	0x64
SDR's Respond	SDR-IP header LSB	SDR-IP header MSB	Control Item code LSB	Control Item code MSB	Channel number	RF gain value
	0x06	0x00	0x38	0x00	0x02	0x64
Example description	This command sets RF Gain to +14dB (0x64) for RX channel's 2 (0x02)					

RF gain value has next property:

- When this parameter equal to 0 or negative, it should be translated as SDR-IP parameter
- When this parameter defined in the range from 1 up to 127 - it should be translated as AFEDRI SDR-Net RF gain parameter in same way as for USB HID protocol.

Below is the new command for AFEDRI SDR-Net support (is not presented in SDR-IP protocol), required for correct sample rate calculation and calibration purposes.

Request Main Clock frequency (AFEDRI SDR-Net, TCP command)

Command PC -> SDR	SDR-IP header LSB	SDR-IP header MSB	Control Item code LSB	Control Item code MSB	-	-	-	-	-
	0x04	0x20	0xB0	0x00	-	-	-	-	-
SDR's Respond SDR -> PC	SDR-IP header LSB	SDR-IP header MSB	Control Item code LSB	Control Item code MSB	Channel (not used)	Main Clock Frequency			
	0x09	0x00	0xB0	0x00	0x00	byte 0 (LSB)	byte 1	byte 2	byte 3 (MSB)
						0x00	0xB4	0xC4	0x04
Example description	This command requests the main clock frequency value for calibration purposes or for correct sample rate calculation, the answer is 80000000 Hz i.e. 0x04C4B400								

4. Correct sample rate value calculation procedures

This information related to single channel AFEDRI SDR-Net as well as to dual channel models AFE822x SDR-Net (AFEDRI SDR-Net x2, AFEDRI SDR-USB-HS, AFE822x SDR-USB-HS).

The problem that any AFEDRI / AFE822x SDR can be assembled with different sampling Main Clock, this difference can be defined according user request or/and hardware limitation. For example present days next value can be found in networked AFEDRI/ AFE822x SDR:

- 72MHz (was installed in first AFE822x SDR-Net revisions)
- 76.8MHz (mostly installed in current AFE822x SDR-Net revisions, but also in some “special request” AFEDRI SDR-Net)
- 80MHz (installed in most AFEDRI SDR-Net)

To get correct sample rate value user how to do the next sequence:

- I. Request from AFEDRI / AFE822x SDR the Main Clock Frequency value, sending over network “Request Main Clock frequency” command (described in paragraph 3.IV)
- II. use the function below to calculate real sample rate, that correspond to Main Clock Frequency:

```
unsigned long get_sample_rate(unsigned long main_clock_freq, unsigned long
requested_sample_rate)
{
    unsigned long temp = 0;
    unsigned long real_sample_rate = 0;
    temp = main_clock_freq / requested_sample_rate;
    temp = temp / 4;
    if( main_clock_freq > requested_sample_rate * (4 * temp+2))
    {
        temp = temp + 1;
    }
    real_sample_rate = main_clock_freq / (4 * temp);
    return real_sample_rate;
}
```

where input parameters are next:

- main_clock_freq - Main Clock Frequency value requested from SDR (or use default value = 80 000 000)
- requested_sample_rate - the desired sample rate that you want to use

The output result will be real sample rate value that SDR can set according Main Clock Frequency oscillator used inside AFEDRI/AFE822x