WRplus 1.06 by Sandro Sfregola **© SDR Applications** 23/09/2011

Update to the Winrad User Guide

Contents:

1.0 Notch Filters

1.1 Notch filters overview

Two identical and independent <u>pre AGC</u> powerful notch filters with adjustable frequency and bandwidth have been implemented in WRplus; very deep notches are possible (>100 dB).
The filters are placed before the AGC (as in best radios) and not simply in the audio path: if AGC is enabled, notching a disturbing signal has the effect of raising the level(s) of the wanted signal(s). Several options for quickly tuning the filters are available (like "point and click" in Spectrum2); tuning resolution is down to 0.1Hz; the user can choose an option to see the effects of the filters on the SP2/WF2 display. The notch filters don't introduce additional "processing delay" and need very low DSP CPU resources. An option locks the filters to the received frequency (in SSB and CW) so the user can retune the receiver without retuning the notch filters.

1.2 Controls and operation

The buttons panel in the lower right part of the main window (Fig. 1-1) has been rearranged to make room for new controls: you will find three additional buttons (in comparison to Winrad OS); those buttons are labelled **Notch1**, **Notch2** and **Nlock**. Notch1 and Notch2 buttons engage the respective notch filters. Nlock button engage the Notch Lock function that we will see later. When a notch filter is engaged, its respective button is lit and if WRplus is "running" a coloured vertical dotted line (marker) is displayed in the SP2 window, at the current filter frequency. Looking at Fig. 1-2 you will notice three vertical lines in SP2: (from left to right) the blue marker for Notch1, the pink marker for Notch2 and the "click and tune" cursor (a solid yellow line) at mouse cursor position.

Fig. 1-1 Rearranged buttons

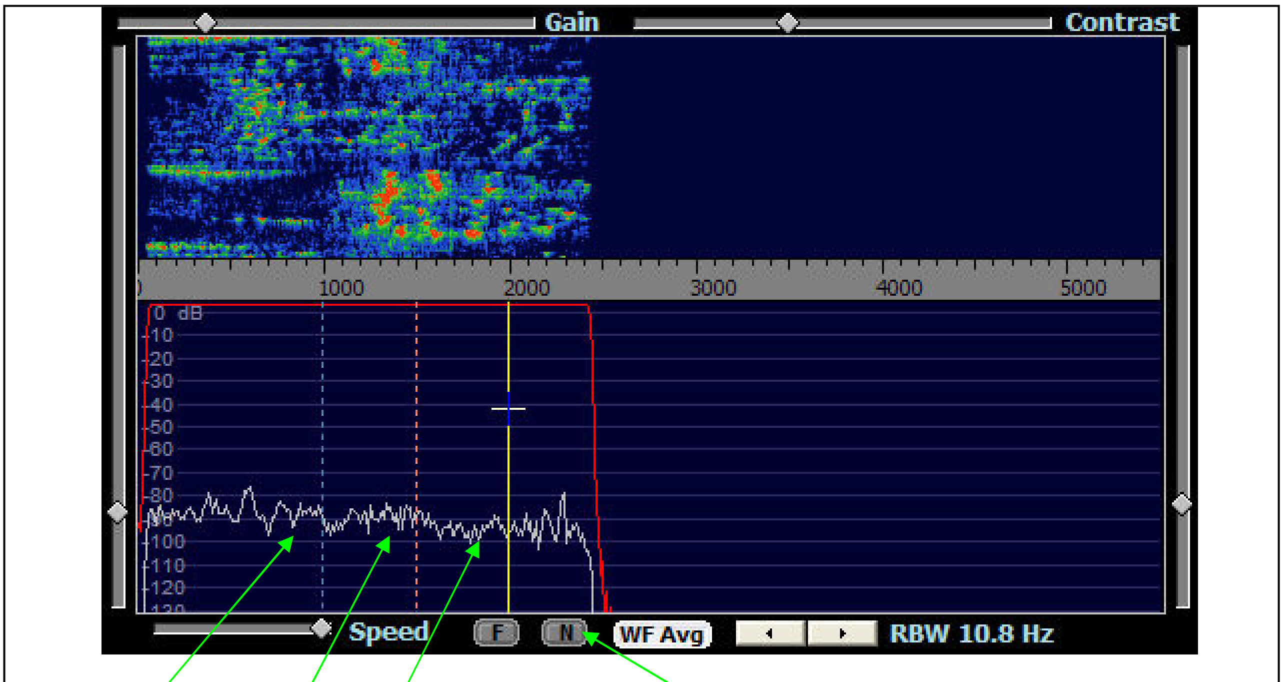

Fig. 1-2 New notch-related items inside and around SP2/WF2

The latter is displayed only when the **[Shift]** key is pressed and at the same time the mouse cursor is in Spectrum2 area; its purpose is to allow for fast tuning of the notch filters. Let's see an example: you have an offending carrier, visible on SP2/WF2 that you wish to notch out: engage either of the notch filters then move the mouse cursor inside SP2 area while keeping the **[Shift]** key pressed, the "click and tune" cursor will appear; move it at the spectrum position where you see the disturbing carrier then assign that frequency to Notch1 by mouse **[Left Click]** or to Notch2 by mouse **[Right Click]**. The markers on the SP2 and the Notch Filters panel will reflect the updated frequency.
The "click and tune" feature is useful but its precision is dependent upon the current spectrum resolution; other tools for refining the filters tuning (and also to adjust the filters bandwidth when needed) are implemented inside the Notch Filters panel (Fig. 1-3); it is always visible showing all the notch filters current parameters values and allowing for quick editing of them.

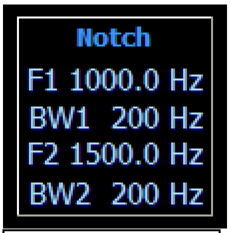

Fig. 1-3

In order to change the value of one parameter it must be highlighted first by placing the mouse cursor over it: the background colour of the highlighted parameter will change from black to blue for Notch1 parameters (Fig. 1-4) or from black to pink for Notch2 parameters (Fig. 1-5); then the value can be changed as follows:

For frequency parameters (F1, F2):

- **[Mouse Wheel]** increment/decrement by 1 Hz steps
- **[Ctrl] + [Mouse Wheel]** increment/decrement by 0.1 Hz steps
- **[Shift] + [Mouse Wheel]** increment/decrement by 10 Hz steps
- **[Left Click]** decrement by 100 Hz steps
- **[Right Click]** increment by 100 Hz steps
- **[Shift] + [Left Click]** decrement by 1000 Hz steps
- **[Shift] + [Right Click]** increment by 1000 Hz steps

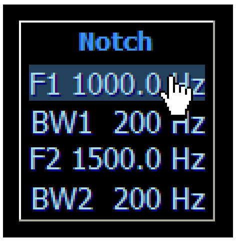

Fig. 1-4

For bandwidth parameters (BW1, BW2):

- **[Mouse Wheel]** increment/decrement by 10 Hz steps
- **[Shift] + [Mouse Wheel]** increment/decrement by 100 Hz steps

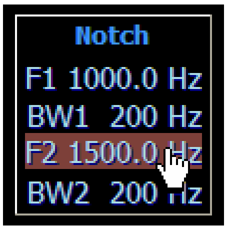

Fig. 1-5

Clicking the mouse right button while the cursor is over the Notch1 or Notch2 button will pop-up the Notch Filters menu (Fig. 1-6).
The purpose of the available options is quite self-explaining: the **Copy Notch1 -> Notch2** option will set the frequency and bandwidth values of notch filter 2 identical to those of notch filter 1; the **Copy Notch2 -> Notch1** option will do the same with the source and destination exchanged; **Reset Notch Filters** will set all the notch filters parameters to the start-up values. Let's see now the purpose of the **Notch Lock** function in a typical usage scenario: you are following a SSB QSO where some operators are slightly off frequency when a heterodyne tone caused by a nearby unknown CW emission appears; you could easily reduce or eliminate that disturbance by engaging and tuning one of the notch filters; but when you have to retune the reception frequency to follow the off frequency stations the frequency of the beating signal change as well, and you have to retune the notch filter again; all of this work can be annoying and distracting. Once enabled, the Notch Lock function will do the correction of the notch filters frequency automatically as the reception frequency is varied, taking into account the reception mode (it works in LSB, USB or CW mode only).

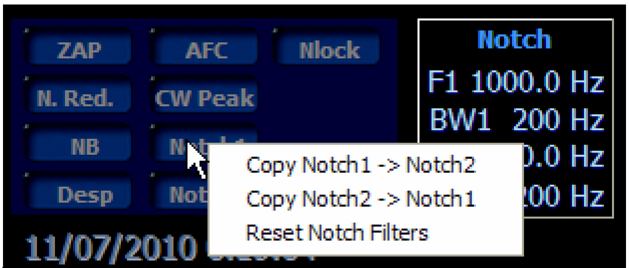

Fig. 1-6

The keyboard shortcut **[Ctrl] + [N]** can be used in place of the Notch1 button.

It can be useful to see how the spectrum of the received signals is affected by the notch filters; that is the purpose of the small **N** button placed below the SP2 window (Fig. 1-2): if enabled it places SP2/WF2 after the notch filters in the signal path.

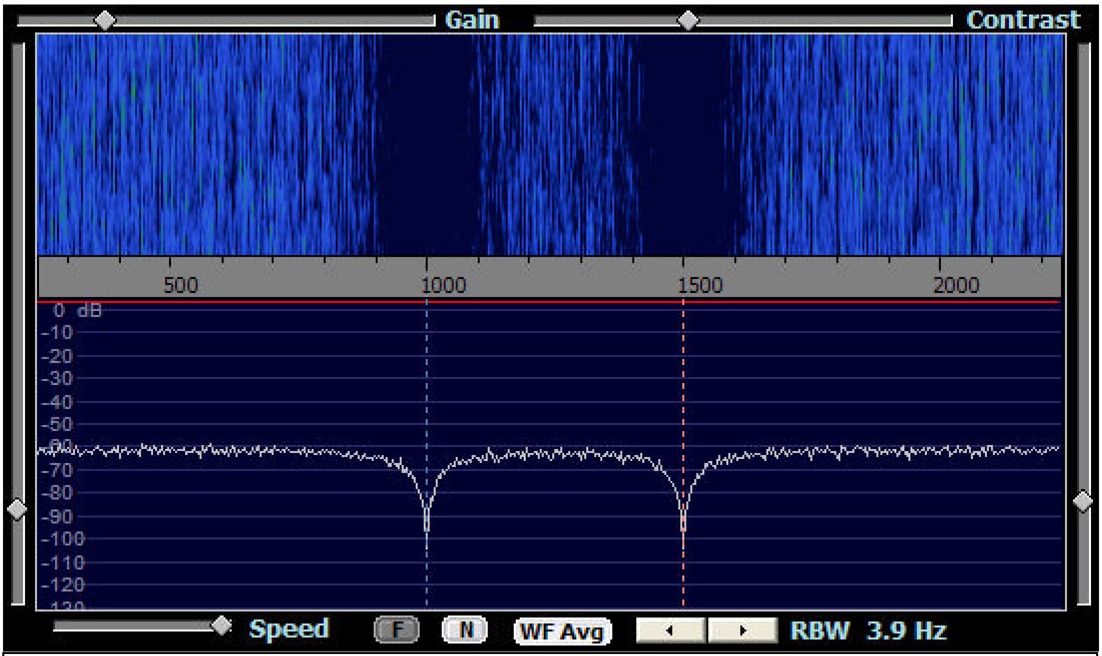

Fig. 1-7

As an example, I have fed a white noise signal to the input of WRplus to take the above picture: mode is SSB and the waveform average for SP2/WF2 is set to 16, both notch filters are enabled and the relative parameters are set to default values.

Please note that the effective attenuation of the filters is much greater than what is visible in Fig. 1-7 due to the lack of spectrum frequency resolution.

The **N** button is disabled if the **F** button is enabled (CW full): the two functions are incompatible.

1.3 About the Notch Filters parameters

The frequency parameter refers to the converted 0Hz IF as seen in SP2/WF2; the minimum frequency has been fixed to 10 Hz, the maximum is automatically computed by the program to be about ½ of the internal SR.
The bandwidth parameter specify the -3 dB response of the filter: a 200 Hz value means that the response will be -3 dB at +/- 100 Hz around the current filter frequency; the minimum bandwidth (max **Q**) has been fixed at 10 Hz, the maximum at 3000 Hz.

The current filter settings are not saved in the registry when the program terminates; every time WRplus is started, the notch filters parameters are restored to their default values.

1.4 Tips and funny experiments

As above stated, the bandwidth parameter specify the -3 dB response of the filters but the "deepest notch" bandwidth is very narrow in comparison: a tuning difference of even 0.1 Hz can make a big difference in terms of signal attenuation. So when a deep notch is required an accurate tuning is essential. Raising the bandwidth will help a bit but this also will make the filter "more invasive"; the default value is a good starting point for everyday use. At bandwidth settings below 50 Hz the ringing of the filter will cause a drop of the apparent attenuation, more noticeable on impulsive signals (as CW). In lab tests I have measured attenuations of more than 120 dB at 1000 Hz (the theoretical maximum attenuation is only limited by rounding of the *single precision* variables involved). As a demonstration of the capabilities of the notch filters I suggest a simple and interesting experiment: tune your WRplus based receiver on a CW HF band portion with strong signals and record some seconds; then replay the recording in loop mode. Select CW mode and tune one of the stronger signals; enable either of the notch filters and carefully tune it on the same frequency of the received signal. At one point you will have the CW tone cancelled out allowing to clearly hear the sidebands, mostly the manipulation click and often some power supply ripple from the operator TX power amplifier, amplitude modulating the carrier.

If you are interested in NDB DX you will also find the notch filters really useful to eliminate unwanted carriers or modulation sidebands.

2.0 FM mode

2.1 FM overview

There is a growing interest in FM these days, lead from the adoption of VHF/UHF down-converters in front of "standard" SDR HF receivers; in Winrad OS the NBFM implementation is quite "experimental" and not working properly from my point of view. Also while working on it I discovered an error that caused the strong aliases I noticed with input sampling rates of 48 KHz and below (this is also true for DRM mode). So I completely redesigned the NBFM mode in WRplus 1.0, adding also some new features; as the complexity grew up, I decided to redesign the FM mode again for release 1.03. The already good demodulation algorithm of WRplus 1.0 has been greatly improved (see below). There are now four FM sub-modes: Narrow FM, Medium FM, Wide FM, and Stereo Wide FM. A broadcast quality stereo decoder has been added. In WRplus 1.04 RDS reception has been implemented.

The current FM features in short:

- New "zero distortion" demodulation algorithm (starting from release 1.03) with almost perfect AM rejection and very good S/N ratio
- Four FM sub-modes: Narrow (0 – 24 KHz BW), Medium (0 – 48 KHz BW), Wide (48 – 192 KHz BW), Stereo Wide (as Wide plus stereo decoder)
- Optional post-demodulation adjustable band-pass filter (512 taps FIR)
- Optional de-emphasis filter with a standard -6dB/oct. curve (-3dB @ 300Hz) for Narrow and Medium FM
- Optional 50uS and 75uS de-emphasis filters for Wide and Stereo Wide FM
- High quality broadcast FM stereo decoder
- RDS demodulation/decoding
- Squelch function (see chapter 3.0)

2.2 New demodulation algorithm

The new demodulation algorithm implemented in WRplus 1.03 provides a near perfect AM rejection, even for strong signals and good S/N ratios through the entire dynamic range available; as its output is only a function of the carrier frequency deviation, the AGC is not required. It is greatly more linear than the previous implemented in WRplus (see next page).

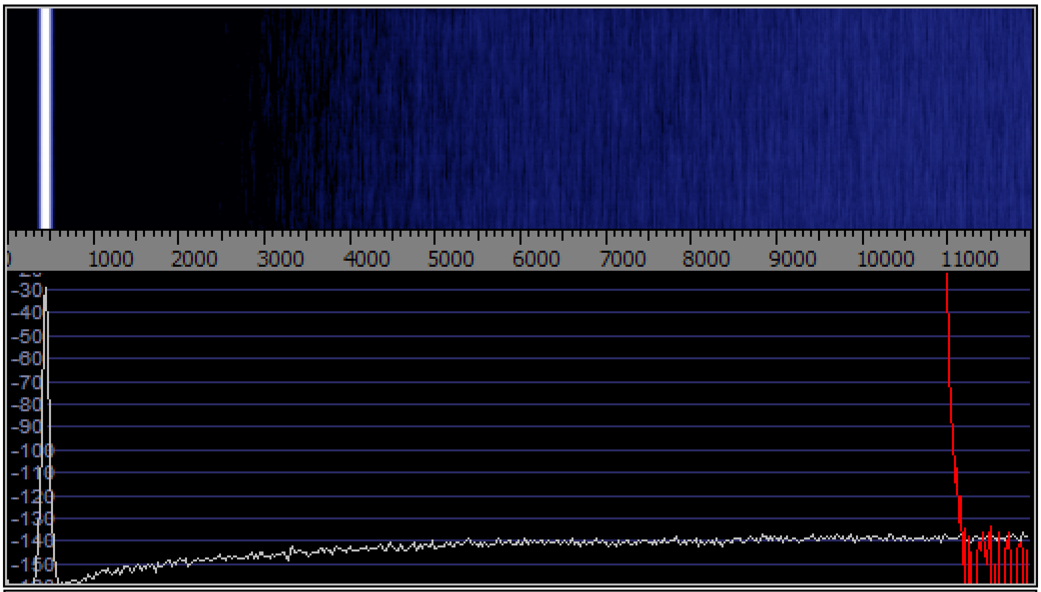

Fig.2-1 New FM demodulator distortion test

The above picture shows the spectrum of a demodulated test signal fed to WRplus; in order to perform this test a high quality FM modulated carrier (F=12KHz, modulation +/- 5KHz @ 440Hz sine wave) has been digitally synthesized as the ordinary lab generators have too much intrinsic distortion. Please note that there are no harmonics of the 440Hz modulating tone visible in the noise free 110 to about 130 dB range below the -30 dB reference level. This means that the (internal) distortion is better than 0.0005%.

2.3 Narrow BW sub-mode

This FM sub-mode allows the demodulation of FM signals with a bandwidth of up to 24 KHz. Processing and output SR are 24 KHz. The powerful 1500+ taps IF filter can be adjusted in the usual way to set the desired BW.

2.4 Medium BW sub-mode

This FM sub-mode allows the demodulation of FM signals with a bandwidth of up to 48 KHz. Processing and output SR are 48 KHz. The powerful 1500+ taps IF filter can be adjusted in the usual way to set the desired BW. This mode is useful for NOAA APT weather satellite reception, which requires at least a 30 KHz BW (I recommend a 38 KHz filter setting) or others “medium BW” applications.

2.5 Wide BW sub-mode

This FM sub-mode allow the demodulation of FM signals with a bandwidth from 48 up to 192 KHz. Demodulation is done at a 192 KHz SR then the signal is decimated to a 48 KHz SR for further processing (the output SR is also 48 KHz). Until release 1.06, for performance issues a 256 taps FIR filter was used in place of the standard “fast convolution” IF filter; the result was still an excellent selectivity, far better than what is obtainable with conventional “hardware” filters (near perfect pass-band flatness, no phase distortion, steep skirts). Now in release 1.06 the filter is even better. There are some selectivity values available as pre-sets and the user can also enter an arbitrary filter width in the range 48 – 192 KHz if needed. All the possible measures to keep the CPU usage low has been taken but still this mode obviously requires more resources given the high internal SR especially if the input SR is also high. If a late generation PC is used, no problems (from Core 2 upwards) but if WRplus is used in combination with Perseus or similar receivers and an older PC, I suggest starting with a 250KS setting.

2.6 Stereo Wide BW sub-mode

This mode is almost identical to the above Wide BW sub-mode with the following exceptions: a broadcast quality stereo decoder (192 KHz processing) is added after the FM demodulator; its outputs are directly routed to the WRplus outputs so the following options won't work:

- Post demodulation band-pass filter
- Notch filters
- Noise Reduction
- Output limiter

When reception is stereo, the SP2/WF2 shows the Right channel signal.

2.7 The new FM options window

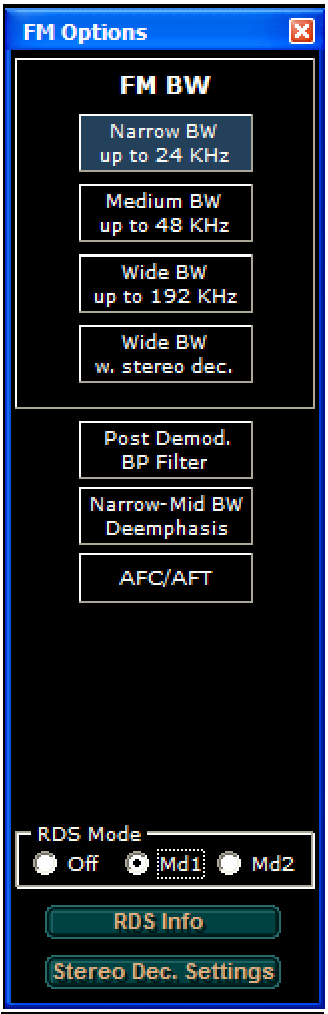

Fig.2-2

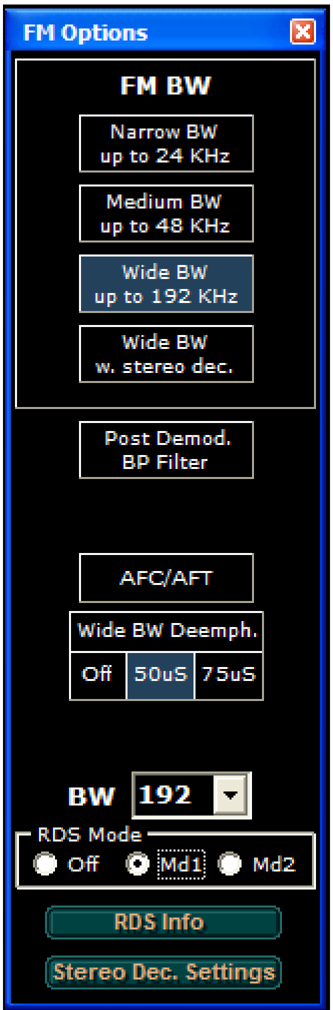

Fig.2-3

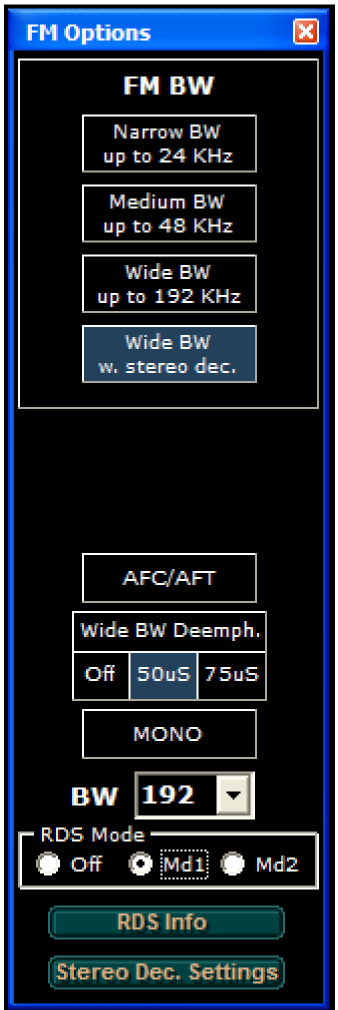

Fig.2-4

Fig.2-2, 2-3 and 2-4 show the new FM options window (Right-click on the FM mode button to pop-up it). Note that the program hides all the controls not applicable to the current selected sub-mode for simplicity. The sub-mode selection is performed by the four buttons inside the "FM BW" frame; they are always visible. The other buttons have quite self-explaining functions. The combo box in the lower part of the window allows the selection of one of the pre-sets filter BW (in Wide FM only) or the direct entry of any value between 48 and 192 KHz (to enter a new value manually select the text first, key in the value then press **[Enter]**.

2.8 Post demodulation band-pass filter operation

In WRplus the FM post-demodulation filter can be enabled/disabled in the "FM options" window (see 2.7); it adds about 10mS (@24KHz SR) to the total signal processing time.

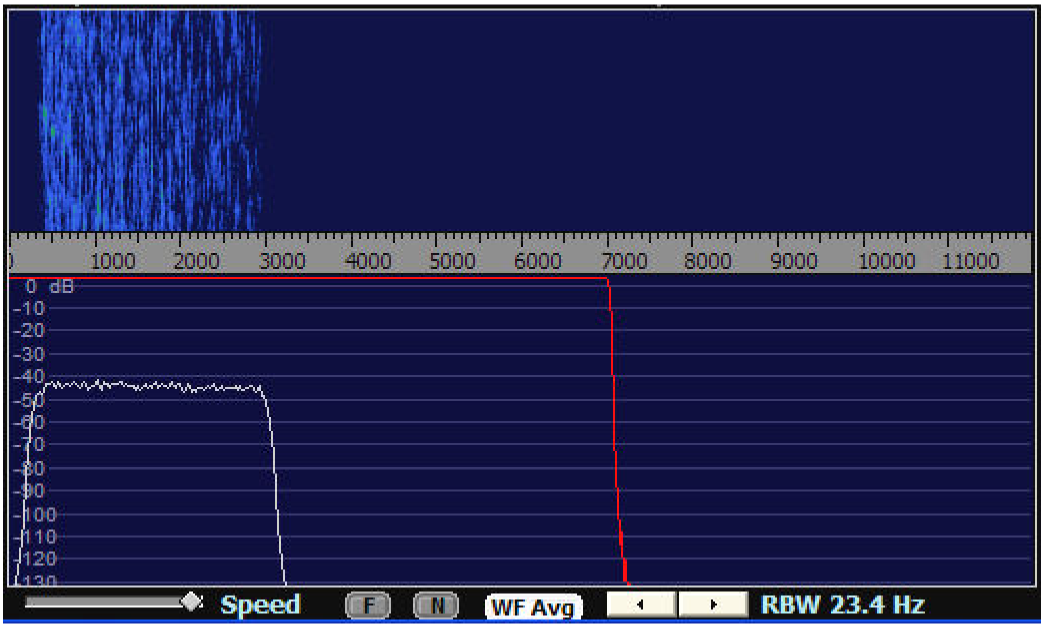

Fig. 2-3 Noise spectrum shaped by the post-demodulation filter

Fig. 2-3 shows how noise is shaped by the post-demodulation filter, whose parameters are set as follow: Lc (low-cut freq.)= 300 Hz, Hc (high-cut freq.)= 3000 Hz. All the filter parameters are displayed, among other things in the FM info panel that is shown in place of the phase-meter display when FM mode is selected (Fig. 2-4). Again, here you can use the "click and tune" feature already seen in paragraph 1.2 to set the low and high cut frequencies: this time use the **[Ctrl]** key instead of the **[Shift]** key to display the "click and tune" cursor; then assign the low cut frequency by mouse **[Left Click]** and/or the high cut frequency by mouse **[Right Click]**. As for the notch filters, you can also highlight the parameters in the FM info panel and change their values as follows:

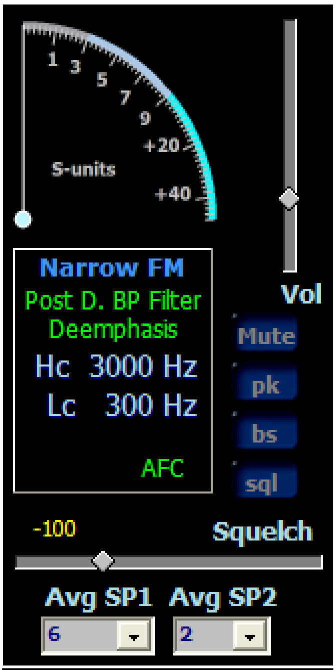

Fig. 2-4 The FM info panel

- **[Mouse Wheel]** increment/decrement by 50 Hz steps
- **[Ctrl] + [Mouse Wheel]** increment/decrement by 500 Hz steps
- **[Shift] + [Mouse Wheel]** increment/decrement by 10 Hz steps

A single pole (6dB/oct.) high pass filter with a -3dB cut-off frequency of 5Hz is always inserted in the signal path in order to remove the DC components resulting from the FM demodulation process.

The current filter settings and all the FM related options are saved in the registry when the program terminates and restored at the next program start-up.

2.9 De-emphasis filters

Several choices of de-emphasis filters are available in the FM options window (see 2-7), depending upon the current FM sub-mode. For Narrow and Medium BW FM a single pole (6dB/oct.) low pass filter with a -3dB cut-off frequency of 300Hz can be selected.
If enabled, the volume loss associated to the emphasis / de-emphasis process is automatically compensated by the program.
For Wide and Stereo Wide BW FM a standard 50uS or a 75uS time constant single pole low pass filter(s) can be selected. The program stores individual settings for Wide and Stereo Wide. For FM broadcast the standard de-emphasis is 50uS in Europe and 75uS in the USA.
The effects of the de-emphasis filters are visible in the SP2/WF2 windows.

2.10 AFC/AFT

This option enables FM Automatic Frequency Control / Automatic Frequency Tracking; this feature locks the internal WRplus NCO to the received carrier frequency, in a way similar to ECSS mode. If the carrier frequency varies continuously as in the case of APT satellite reception (due to Doppler effect), the AFC become AFT, chasing those variations thus maintaining optimal FM demodulation. WRplus 1.03 implements a new, much more CPU efficient AFC algorithm. The AFC/AFT has now a limited range of 90% of the current bandwidth (+/- 45%); when you activate the AFC button WRplus take the current Tune frequency as a reference and compute the limits based on the current filter settings. In order to reset the limits and the centre frequency you must switch AFC off then on again; if needed you can choose a narrow limit by setting the filter appropriately before switching on AFC then re-adjusting the filter to a wider bandwidth or vice-versa. There is a good amount of flexibility.

2.11 FM broadcast stereo decoder

WRplus implements now a high quality stereo decoder; with the appropriate front-end WRplus can be employed in professional monitoring applications.
The quality of the recovered audio is remarkable and this is mainly due to:

- the linearity of the FM demodulator
- the phase linearity of the FIR filters
- the output frequency response flatness up to 15KHz (as per standard specifications)
- the total absence of spurs and beating tones due to the ideal recovering of the L-R information by a multiplier and a true sine regenerated sub-carrier

I'm a hardware designer mainly (since 30 years) and I can reliably tell you that there is no way to obtain this level of performance by conventional hardware only (no DSP).
Now that FM broadcasters also employ high-end digital equipments for encoding it is a pity that they use so much compression: FM could be really a high quality source (much better than low BW digital radio on the internet).

When the decoder detects a pilot tone of sufficient strength it switch on the stereo decoding process; a "Stereo" indication appears in the lower left of the FM info panel.
The "mono" button in the FM options window force the reception to mono (usually for quick comparison). Be sure to have the correct de-emphasis filter selected. The key parameters of the stereo decoder process are tweakable in the "stereo decoder settings" window (Fig. 2-5).

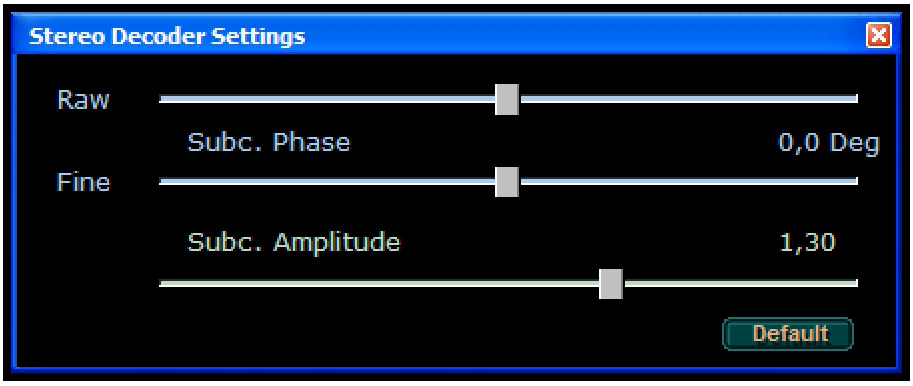

Fig. 2-5

2.12 RDS overview

Radio Data System is available in WFM and SWFM FM sub-modes. There are two distinct processes in order to obtain the RDS information: demodulation and decoding. The demodulation process includes the recovery of the RDS data bit-stream and clock and is usually performed in hardware by dedicated ICs. In WRplus a complex multi-PLL, FIR filtering and AGCs implementation is used for the same purpose. The decoding process includes the reconstruction of the data fields sent by the broadcaster, as defined in the RDS protocol, and is usually performed (in real radios) by the radio microprocessor (and software). In WRplus the decoding core has been kindly provided by Michael Feilen; it is my adaptation of the decoding core of his FMstack SDR software. Unlike other RDS decoders, Michael's code makes full use of the Forward Error Correction feature built in the RDS protocol: this means that data blocks containing errors are not simply discarded but errors are corrected (when possible) using CRC. WRplus is capable of extracting the RDS information even from mono signals, like the stand-alone hardware demodulators/decoders. RDS operation is selectable in the FM options panel (Fig. 2-2, 2-3, 2-4); there are three operational modes: Off, Mode 1 (default) and Mode 2.
Off mode obviously disables all the processes relative to the RDS; select it if you don't need the RDS features: this will save some CPU resources. Mode 1 and 2 are described below in detail.

2.13 RDS Mode 1

RDS Mode 1 works in a way similar to a stand-alone decoder: the regenerated 57 KHz RDS sub-carrier needed for the demodulation is obtained from the RDS signal itself by a special PLL. There are at least two benefits in doing this: the phase is always optimal and the RDS data can be recovered also from mono signals. This mode also uses more CPU resources due to a more complex processing.

2.14 RDS Mode 2

In Mode 2 the regenerated RDS sub-carrier is obtained by multiplying the frequency of the stereo pilot tone (by the stereo demodulator PLL). The RDS standard states: *"…During stereo broadcasts the sub-carrier will be locked either in phase or in quadrature to the third harmonic of the 19 kHz pilot-tone. The tolerance on this phase angle is ±10°, measured at the modulation input to the FM transmitter…"*. As the pilot tone is far more "robust" than the RDS signal itself (10% deviation against about 2.6%) one could think that it is better relaying on it for the demodulation; in practice things are a bit different. Some broadcasters are way out of standards for what concern the phases relationships (pilot to RDS sub-carrier and pilot to RDS data). Anyway, WRplus demodulation is auto-adapting for the most part.

2.15 Which mode should I use?

My advice is: start with Mode 1 then (if the broadcast is stereo) in case try Mode 2. The best mode depends on too many factors. To FM DX'ers: do not expect miracles; there is a certain minimum S/N ratio for the RDS to work. RDS was not conceived for DX (just see the standard) but to be a non invasive mode to broadcast a slow digital data stream. Sometimes you get a good audio but no RDS at all as there are disturbances only on the highest part of the channel baseband spectrum, where the RDS signal is placed. In a future release I will consider to implement a FM baseband spectrum mode to see the actual signal on the SP1 window.

2.16 The RDS sync indicator

Fig. 2-6

When the RDS decoder achieves sync with the incoming data, an RDS indicator shows up in the FM info panel (Fig. 2-6). Flickering of this indicator is normal if the signal is less than optimal. See also the other status indicators in the RDS info window.

2.17 The RDS info window

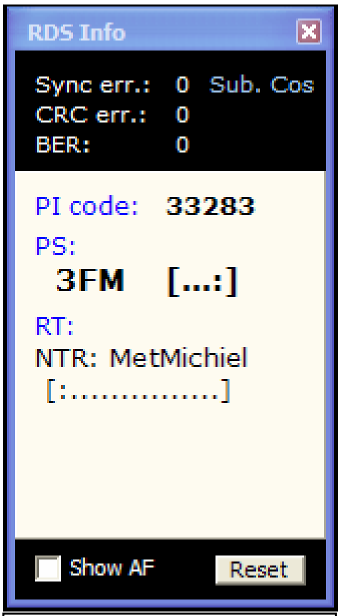

Fig. 2-7

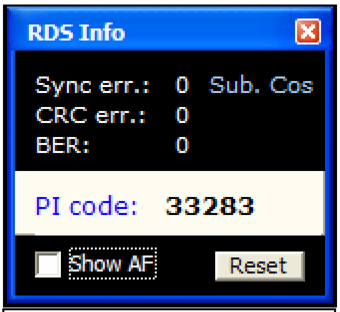

Fig. 2-8

The RDS window provides the formatted RDS decoded data, status information and some controls. To pop-up the window click on the "RDS Info" button in the FM options panel (Fig. 2-2). It is fully resizable upon the user needs. Fig. 2-7 shows the initial size of this window while Fig. 2-8 shows a reduced version where only the PI code is visible. The black background areas are not stretched while varying the window height as they contain status information and controls. RDS data fields instead are placed inside the white area. Some words about the status fields:

- **Sync err.**: it shows the accumulated number of sync errors during reception
- **CRC err.**: it shows the accumulated number of CRC errors during reception
- **BER** or Bit Error Rate: it expresses the quality of the received data showing the number of incorrect bits divided by the number of received bits; for example a BER of 0.001 means one erroneous bit in 1000 received bits. The lower the better.

The displayed RDS data fields are: **PI** (Programme Identification), **PS** (Programme Service), **RT** (Radio Text) and optionally **AF** (Alternative Frequencies). All the above status and data fields are cleared when the decoder detects a new PI code or the **Reset** button is clicked (this button also issue a reset to the decoder logic). In the following page there are some examples of RDS reception with and without the AF list; the latter shows the last 20 AF received.

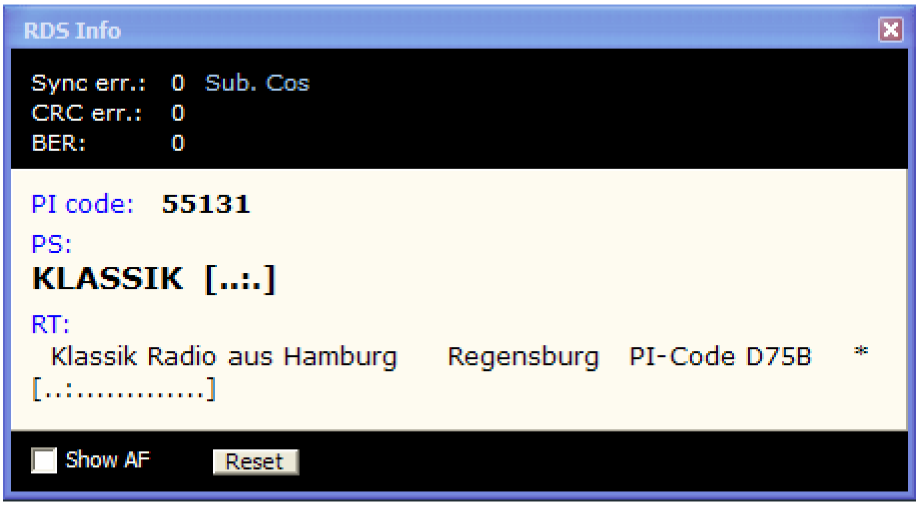

Fig. 2-9

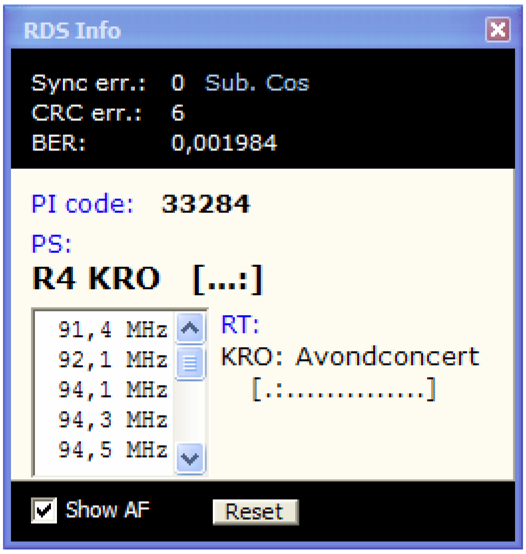

Fig. 2-10

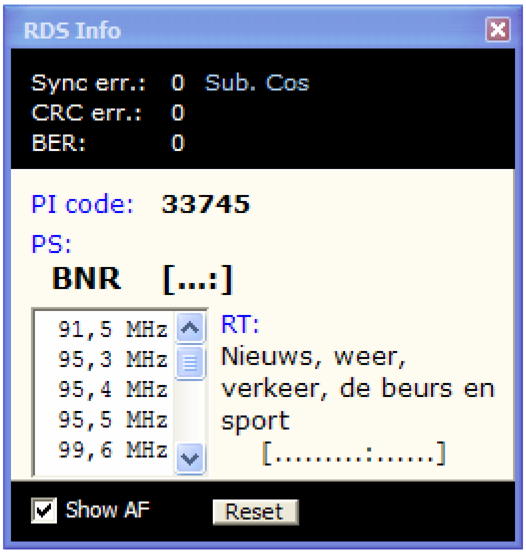

Fig. 2-11

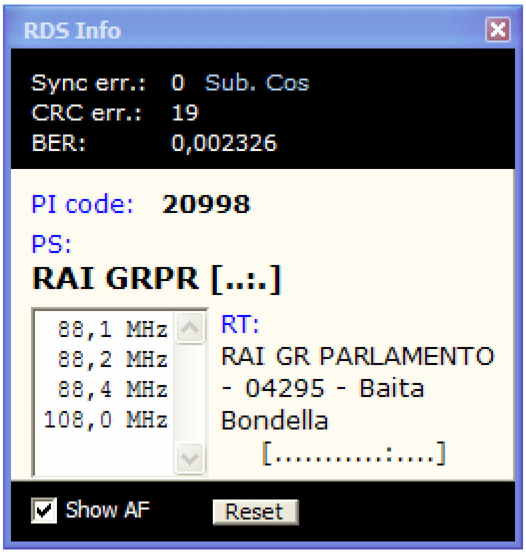

Fig. 2-12

3.0 Squelch

3.1 Squelch overview

A carrier level based squelch function has been implemented in WRplus.
The squelch features independent time constants including hang time, signal averaging and hysteresis for a smooth operation.

3.2 Squelch controls and operation

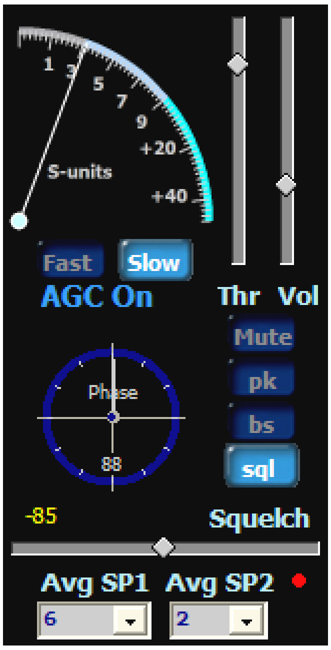

Fig. 3-1

The squelch threshold level can be set from -120 to -50 dB by the Squelch cursor (Fig. 3-1); the current level is displayed by a small yellow label. The squelch can be enabled/disabled by the **sql** button. When enabled, a coloured dot located to the lower right of the squelch cursor shows the squelch internal status: if red, it means that the signal is under the squelch threshold and the receiver is muted; otherwise a green colour means that the squelch is open. A 3dB hysteresis and signal averaging minimize "stuttering" due to noise. An optimized hang time is automatically chosen upon the current reception mode; it is very short for FM (where a stable carrier exists and the squelch must close quickly) and much longer for SSB.

4.0 S-meter

4.1 S-meter overview

The S-meter implemented in WRplus features:

- optimized time constants, independent from those of the AGC
- true average or peak modes
- peak hold
- calibration capabilities in a +/- 100 dB range

A floating, bigger and resizable S-meter is available for better readability. The S-meter is quite accurate and can be used as a true measuring instrument: there is a small linearity error that is not caused by the program algorithms but by the S-meter VCL object; this will be fixed in a future release. The S-meter full-scale is S9+50 dB; a difference of one S unit corresponds to a signal level difference of 6 dB as per IARU Region 1 Technical Recommendation R.1.

4.2 S-meter controls and operation

Fig. 4-1

The S-meter provide two main working modes, average or peak, the selection being done by the button located under the "**Mute**" button (see Fig. 4-1); left-clicking this button alternate the mode and the button caption change accordingly ("**pk**" or "**avg**"); right-clicking the same button pop-up the S-meter options dialog window (Fig. 4-2). The larger, resizable S-meter (Fig. 4-3) can be opened/closed by the **bs** button. The option "Enable Hold in peak mode" can be quite useful in SSB and CW modes: it freezes the maximum value indicated for a given time allowing for a quick and easy reading of the signal peak level; it is enabled by default.

According to the reception mode the S-meter shows:

- in AM mode, the level of the carrier plus the superimposed modulation
- in FM and CW mode, the level of the carrier
- in ECSS, SSB and DRM modes, the level of the selected sideband(s)

4.3 S-meter calibration

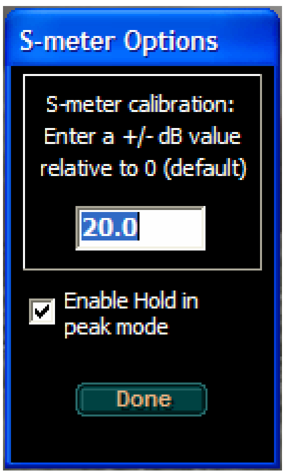

Fig. 4-2

The S-meter can be easily calibrated; the default value (+25.0) set the **S-9** point of the scale to an input level of **-50 dB**. To enter a different calibration value in dB, open the S-meter dialog window, select the value in the edit box and key-in a new one (including one decimal place if required), then press **[Enter]**. If the value has been accepted, the edit box will show it (and the S-meter indication will reflect the new setting). The calibration range is between **99.9** and **-99.9**; a positive number will make the S-meter *less sensitive*. A zero value will set the standard Winrad S-meter sensitivity.

S-meter calibration of a complete reception system should be performed using as a reference an un-modulated carrier of a known level (CW from a generator), placing WRplus in AM mode and the S-meter in average mode.

The current S-meter settings and all its related options are saved in the registry when the program terminates and restored at the next program start-up.

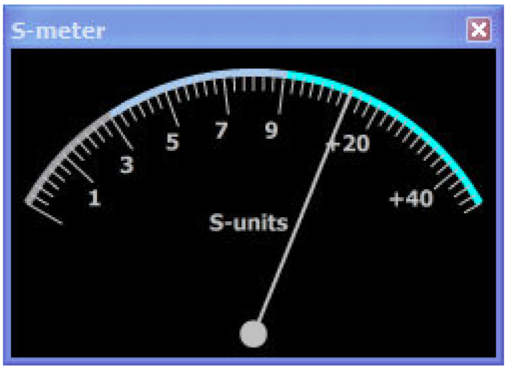

Fig. 4-3 The floating resizable S-meter

5.0 AM (and ECSS) mode improvements

5.1 The high-pass filter and the Winrad AGC issue

When demodulating an AM signal using envelope detection (it does not matter if in the analog or digital domain) you get the modulating signal superimposed to a DC component; the latter is the average carrier level that, in conventional analog radios is turned to the AGC stage that in turn use it level to control the RF/IF stages gain and the S-meter.
A simple capacitor is used to decouple the DC (a basic high-pass filter) and recover the audio that is fed to the AF stages etc. You have probably noticed something strange while using Winrad in AM mode: if you tune an un-modulated carrier (or during modulation pauses) the S-meter doesn't show the signal strength and the AGC starts to pump-up the noise as if there were no carrier; very strange you might think. The reason of that odd behaviour is that in the original Winrad the above mentioned DC component is filtered out <u>before the AGC</u> (and the S-meter) stage; so the AGC works more as an audio compressor and when there is no audio the gain goes thru the roof, raising the background noise.
In order to correct this I have added an option, the "High-pass Position" mode: now you can choose to place the high-pass filter <u>after the AGC</u>; this way WRplus acts as a conventional radio, the AGC "sees" the carrier and the audio level is a true function of the modulation index (you will notice the DC level on the extreme left of the Spectrum2 display as well). The "High-pass Position" mode is selectable in the "AM Options" dialog window (Fig. 5-1) that is shown by right-clicking the AM mode button. *Please note that in WRplus the S-meter always shows the DC + modulation components (see 4.2) regardless of this setting.* Further more, you have probably also noticed that the demodulated audio sounds "thin" with a lack of low end, most noticeable on male speech and music, compared to the ECSS demodulation mode: this is because the cut-off frequency of the high-pass filter is originally 150Hz and the filter is quite steep (a 3rd order filter). I have added an option to select a 50Hz cut-off frequency (with the same steepness) so you can choose what better suit your reception needs.

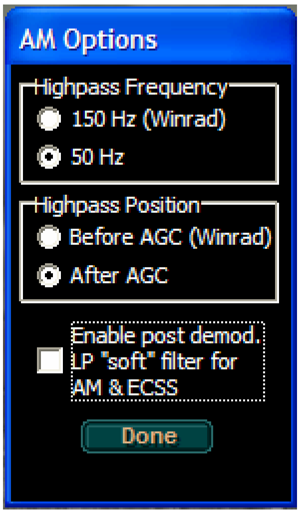

Fig. 5-1

5.2 Introducing the "Soft" low-pass filter

The Winrad main IF filter provide excellent selectivity with his 1500+ taps; nevertheless you have probably noticed some "harshness" in AM (and ECSS) broadcast listening.

This is not a defect of Winrad: the harshness is caused by the ringing that every high-selectivity filter inevitably introduce.

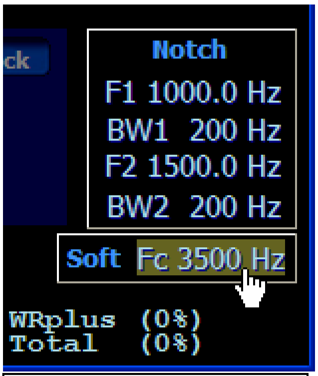

Fig. 5-2

It is well accepted among SWL and radio enthusiast in general that for AM reception a compromise has to be found between selectivity and audio quality. Since varying the selectivity of the main IF filter is not practical in our case, I have implemented a "simple" workaround: the thought behind is that, if we can't avoid ringing, we can move it to a frequency where it is not causing troubles. This can be done adding a second, way less selective, adjustable low-pass filter after the demodulation, the "Soft" filter.
The Soft filter can be enabled in the AM options dialog window (Fig. 5-1); it works in AM and ECSS modes only. The Soft panel is displayed just under the Notch panel (Fig. 5-2). There the Soft filter cut-off frequency (-6dB) can be set (as already seen for the Notch and the FM filter parameters) by the mouse wheel in +/- 100Hz steps.

5.3 The "Soft" low-pass filter in use

The Soft filter response (Fig. 5-3) has been carefully selected after several listening sessions (of course I'm always open to suggestions); note the "gentle" roll-off.

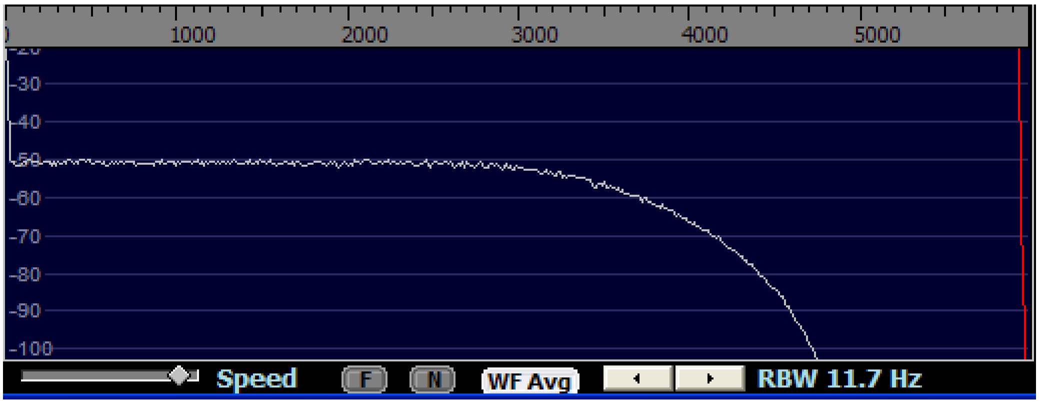

Fig. 5-3 The "Soft" filter frequency response (Fc = 3500 Hz)

The trick works well as long as the main IF filter ringing is placed in the roll-off curve of the "Soft" filter where the attenuation is at least 15-20dB (about 4200Hz in the above example).

Please note that in AM mode the IF filter ringing frequency equals its Fc only if the tuning frequency is the same of the carrier (in ECSS this is always true): if you are detuning in order to shift the pass-band towards one of the sidebands, this shift must be taken into account.

Using this feature require a minimum practice (isn't it part of the hobby btw?) but it is much simpler than how it appears at first sight. For best results, both filters must be adjusted according to the channel situation and the wanted bandwidth.

5.3 The new default IF sampling rates

In Winrad the internal IF sampling rates for AM, ECSS, SSB and CW modes are 8000 or 11025Hz depending upon the current I/O sampling rates and drivers used. In WRplus the IF sampling rate of 8000 Hz has been augmented to 12000 Hz. There are two main reasons for this: the first is that some AM broadcasters use a modulation bandwidth that far exceed the standard maximum +/- 4500 or 5000Hz in order to achieve a better audio fidelity; the second is that the greater the IF sampling rate, the lesser the internal processing time (in this case reduced by 1/3 factor). I'm considering also adding, in a future release, an option for an AM IF of 24000 Hz.

All the current AM options settings are saved in the registry when the program terminates and restored at the next program start-up.

6.0 Various new features and improvements

6.1 Look-ahead AGC

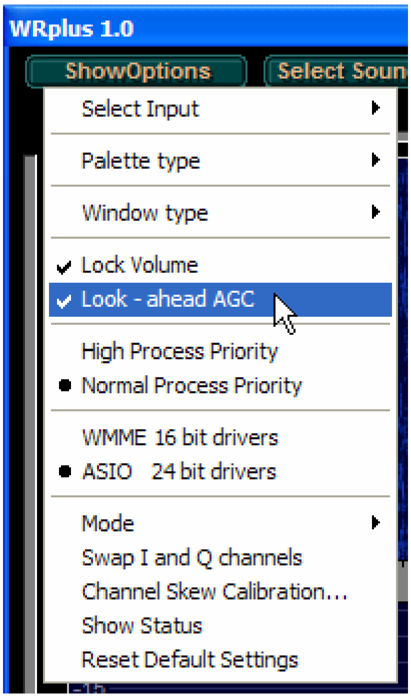

Fig. 6-1

A practical digital AGC must have a finite attack time, otherwise large distortion and digital artifacts would be produced. The AGC implemented in Winrad of course complies with the above rule. Nevertheless, a zero or near zero attack time is often desired, especially when the AGC release is set to fast; you have surely experienced the annoying high-level transient produced by the AGC when the received signal strength rise abruptly (e.g. SSB or CW modes). Luckily, a well known workaround exists and is generally called "the look-ahead technique" that in WRplus is implemented in the AGC and in the output limiter (see 6.2). Look-ahead literally means "to see in advance for an event to happen" (or a future event prediction if you like); please don't laugh: I know that the time machine has yet to be invented but the same result can be achieved if you change your point of view along the time axis. Putting it in another way: you can't really predict a signal event but if you put a delay in the signal path and consider the delayed signal your "real-time" one, then you have access to "future" events: the un-delayed signal (a poor-man time machine). This technology is simple to implement in the digital domain but has been used for decades even in analog devices such oscilloscopes, TV sets, professional audio gear etc. using analog delay lines. In WRplus the AGC look-ahead option can be enabled in the main options menu (Fig. 6-1) and it is enabled by default. The look-ahead time is just a bit longer than the AGC real attack time; the final result is a true zero attack time AGC. You can download example audio files from the WRplus web site and listen to the same signal with and without this option enabled.

The current "look-ahead AGC" option setting is saved in the registry when the program terminates and restored at the next program start-up.

6.2 Brick-wall, distortion free output limiter

In WRplus, a new output limiter has been implemented; it also uses the look-ahead technique seen above. The limiter prevents the output signal to rise above about -2 dB relative to Full Scale thus avoiding digital hard clipping. The limiter is always inserted and its intervention is indicated by the volume cursor background turning to red: this event doesn't mean that distortion is occurring but it is simply an indication that some compression is taking place. The compression-limiting action can be deliberately achieved simply raising the volume cursor, providing that the lock volume option is enabled (Fig. 6-1); if the volume control is not locked it will be automatically adjusted by the program to avoid limiting. Hold and release time constants have been carefully chosen in order to provide a "good sounding" compression; it is a "simple" single-band design.

6.3 New DSP engine (and further performance improvements)

WRplus feature a new, highly optimized DSP engine that exploit all the new instruction set extensions of current Intel CPUs, starting from the Pentium 4 (SSE, SSE2, SSE3, SSE4.1, SSE4.2 etc.); this renewed DSP engine has made possible the implementation, among other things, of much better anti-alias filters (see 6.4) while maintaining a reasonable CPU load.
While developing release 1.04 a serious (and unexpected) performance "bottleneck" in the original Winrad code has been discovered and fixed; the improvement in terms of less used CPU resources is dramatic: previously I had on my reference system (an "old" Pentium 4 HT @ 3 GHz) a CPU usage of around 20 – 25% while playing a 500KS file. The maximum sample rate that my system handled was 1000KS: at 2000KS I experienced continuous "stuttering". Now with release 1.04 I have around 25% CPU usage while playing a 2000KS file at maximum SP1/WF1 zoom factor (RBW 122 Hz); at RBW = 244 Hz CPU usage is about 15%. Further more, I'm able to play a 2000KS file in Stereo WFM mode (RDS enabled, Mode 1) with a CPU load of about 30% @ RBW = 1953 Hz. This great improvement means that users will be able, in several cases, to exploit the highest input sample rates without being forced to upgrade their PCs.

6.4 New decimation anti-alias filters

In order to reduce the large input sample rate (up to 2 million complex samples for a total of 4 million per second with Perseus SDR) WRplus (as Winrad) uses up to 5 identical decimation stages followed by a fractional down-sampler stage; each decimation stage first filter the signal then down-sample it by a 2 factor. The first decimation stage is very critical in terms of performances (and maybe the most critical in the entire program) as it has to provide adequate filtering while processing up to 4 million of *floats* per second. WRplus implements a different kind of anti-alias decimation filters (thanks to the new DSP engine) in comparison to

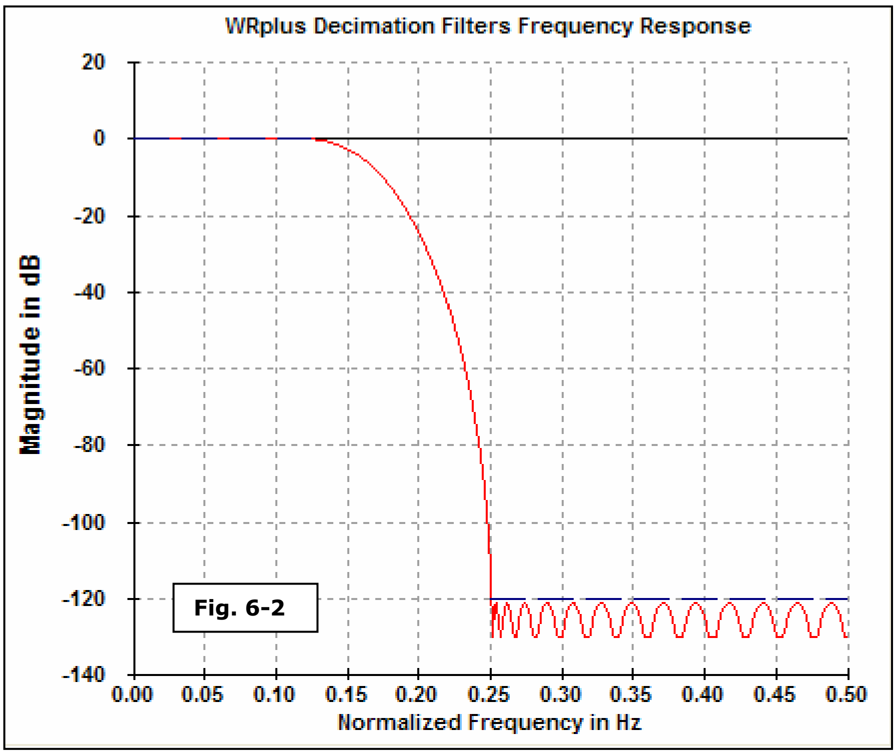

Fig. 6-2

Winrad; here the improvement over Winrad is remarkable: the new filters feature each a worst-case < 0.2 dB pass-band ripple (for a total max < 1 dB ripple) and 120 dB stop-band attenuation (Fig. 6-2); this means that alias products are attenuated at least by 120 dB; in comparison I have measured a worst case 30 dB on Winrad (the same for WinradHD and WinradF as all use the same filters). Alias immunity is critical for a SDR software like WRplus (and in SDR in general) as this parameter has considerable impact on the reception quality; most of you already know the implications but let me show to the less technical readers, how alias can affect reception by a brief example: you have a typical reception system based on a "Softrock" hardware and Winrad software; the Softrock receiver I/Q outputs are connected to the inputs of your sound card, Winrad is set to use the ASIO drivers at an I/O SR of 48 KHz and the Softrock LO is tuned to 6000 KHz. You wish to listen to a weak broadcast AM station on 6006 KHz so you set the tuning of Winrad accordingly; promptly a strong heterodyne tone at about 3000 Hz shows up: looking at the SP1 window there is not such a signal at the input, the only strong signal visible is a S9+40 dB AM broadcaster at 6015 KHz. This "ghost" signal at 6009 KHz is in fact an alias of the 6015 KHz signal, attenuated by about 40 dB so its strength is now about S9, a still huge signal. The aliasing mechanism can be explained as follow: in the above configuration Winrad needs only one of its decimation stages in order to reduce the input SR to 24 KHz then the fractional down-sampler further reduce the SR (by a factor of 3) to 8 KHz; the decimator filter limits the bandwidth of the signal to 12 KHz before down-sampling to 24 KHz, as anything over would cause aliasing, but the stop-band attenuation is poor (about 40 dB). In fact, our alias is

24 – (6 + 15) = 3 KHz
or
NSR – (WLO + S)

where NSR is the new SR, WLO is the Winrad NCO and S the poor disturbing signal, unaware of causing so much trouble. In WRplus the same alias is attenuated by 120 dB so its strength becomes (given S9 = 50 uV) S9+40 – 120dB = 0.005 uV (microvolt), well under the noise floor. For the sake of simplicity, in the above example we have considered only two signals and one decimator: you can only try to imagine what happen when the program has to deal with a 2 mega-samples input signal. As you can see, alias immunity (or alias rejection) is important as much as other key parameters of a SDR receiver as dynamic range, image rejection, IP3 etc.

In WRplus 1.06 the anti-alias filters has been redesigned for even better performances.

Please note: it is not my intention to lessen the value of Winrad or the value of Alberto's work by any means; indeed, as I have already stated elsewhere I consider Winrad a great program and a source of inspiration for further development; all the considerations exposed here are based on observations of real facts and aimed to improvement, not criticism. Putting together an application like Winrad is a huge task for an individual (hundreds of hours of work) and make it for free is a great gift: I can only thank Alberto for his decision of making the Winrad source public.

6.5 Window view

WRplus can run in its "legacy" full screen mode or in a standard window, if launched with the command line option "**–wv**"; this is actually a useful feature already implemented by DG0JBJ, Mario in his WinradHD. If started in "window view" mode the program will try to build a window as highest as possible (up to 1024 internal pixels) using the available screen space: I recommend keeping only the Task Bar active.

The current window position is saved in the registry when the program terminates and restored at the next program start-up.

6.6 Recording folder

In WRplus it is possible to set a destination folder for the recording files, right-clicking the record button then selecting/creating a folder (this is also a feature already seen in WinradHD).
The current recording folder path is saved in the registry when the program terminates and restored at the next program start-up.

6.7 Mode-dependent filter settings

In WRplus, each reception mode has its own main filter settings, saved in the registry when the program terminates and restored at the next program start-up.

6.8 Average options for SP1/WF1

A new average option (value = 6) has been added in between values 4 and 8 for SP1/WF1.

6.9 Redesigned skew adj. panel

Skew adjustment ranges has been augmented to **0.5 - 1.5** for amplitude and **+/- 15°** for phase with the same original resolution; up to four complete skew settings can be stored (**B-2-3-4**) to be used with different receivers. For example, you can store a "neutral" set-up in "B" for Perseus (which doesn't need compensation), a PMSDR set-up in "2" etc.

6.10 Auto-start and auto-record options

While waiting for a proper record scheduler implementation in WRplus, these command line options allow the creation of start-up scripts for recording purposes. Auto start ("**-as**") simply start WRplus after loading and is useful when you want to record the program output; auto record ("**-ar**"), if used together with auto start put WRplus in record mode within 3 seconds after start thus allowing the recording of a spectrum portion.

6.11 Auto EXTIO selection

In order to make the above recording features useable in combination with every hardware supported (and also to be more user-friendly), WRplus now remember the selection of an EXTIO dll as input device from session to session.

6.12 Second display option

A new command line parameter **"-sd**" move the WRplus GUI to the second monitor (when used in full screen mode) like in WinradHD.

6.13 Extended Tune and LO range

In WRplus 1.05 the range of the Tune and LO dials have been extended from 1 GHz to 2 GHz with the addition of 1 digit; the relative values are passed to the external extio.dll (if any) allowing control of external hardware also in the VHF – UHF bands.

6.14 SP2/WF2 enhanced speed control and range

In WRplus 1.03 the management of the SP2/WF2 update has been redesigned; previously speed control was done in 2X discrete steps and the refresh rate was dependent upon the internal SR. Now the speed has several in-between steps and it is independent from the SR.

6.15 New I/O buffers handling

Upon several reports from users I have reviewed in details the code and changed radically how the program deals with the asynchronous data flow. The fractional down-sampler is always locked now so no more "varispeed" effects or frequency instabilities.
Sometimes if the CPU load is very high and other applications are running, WRplus could drop some buffers (you will experience an audio "dropout"): that is normal.
There is only a way to avoid this: a powerful PC. Try to keep the CPU load down.

6.16 New NCO

WRplus 1.04 features a redesigned Numerically Controlled Oscillator with a very high spectral purity. Together with the already renewed anti-alias filters, this feature has eliminated every residual alias or other spurious products; you will notice a quieter background especially with large input SR.

6.17 New Fractional Down-sampler

As emerged in several performance tests (see also the work of Leif Asbrink), the original Winrad fractional down-sampler (FDS) has a poor attenuation of alias product; WRplus 1.05 feature a totally redesigned FDS with a worst-case alias attenuation of about 130 dB.
In WRplus 1.06 the FDS performs even better.

7.0 WRplus installation

WRplus installation is straightforward:

- Download the zipped package from the WRplus site (WRplus_1.06.zip).
- Create a "WRplus" folder wherever is handy for you.
- Copy WRplus_1.06.zip in the above folder and extract the content in it.
- Create a link to WRplus.exe.

The package includes the following files:

`WRplus.exe`	The WRplus executable
`WinRadPX.dll`	A dynamic link library (must be in the WRplus path)
`WRPnfdc.dll`	A dynamic link library (must be in the WRplus path)
`Winrad_UG_1.32.pdf`	The original Winrad User Guide
`WRplus_UGU_1.06.pdf`	The WRplus User Guide Update (this->guide)

The WRplus settings are stored in the following registry key:

HKEY_CURRENT_USER\Software\WRplus

To de-install WRplus, delete the above registry key and the WRplus folder created during installation.