# Dream DRM Receiver Documentation

Dream is a software implementation of a Digital Radio Mondiale (DRM) receiver. All what is needed to receive DRM transmissions is a PC with a sound card and a modified analog short-wave (MW, LW) receiver.

Main Window

The main window shows up when the Dream software is started. The following image shows the main window as successfully synchronized to a DRM transmission. If not synchronized only "Scanning..." is displayed.
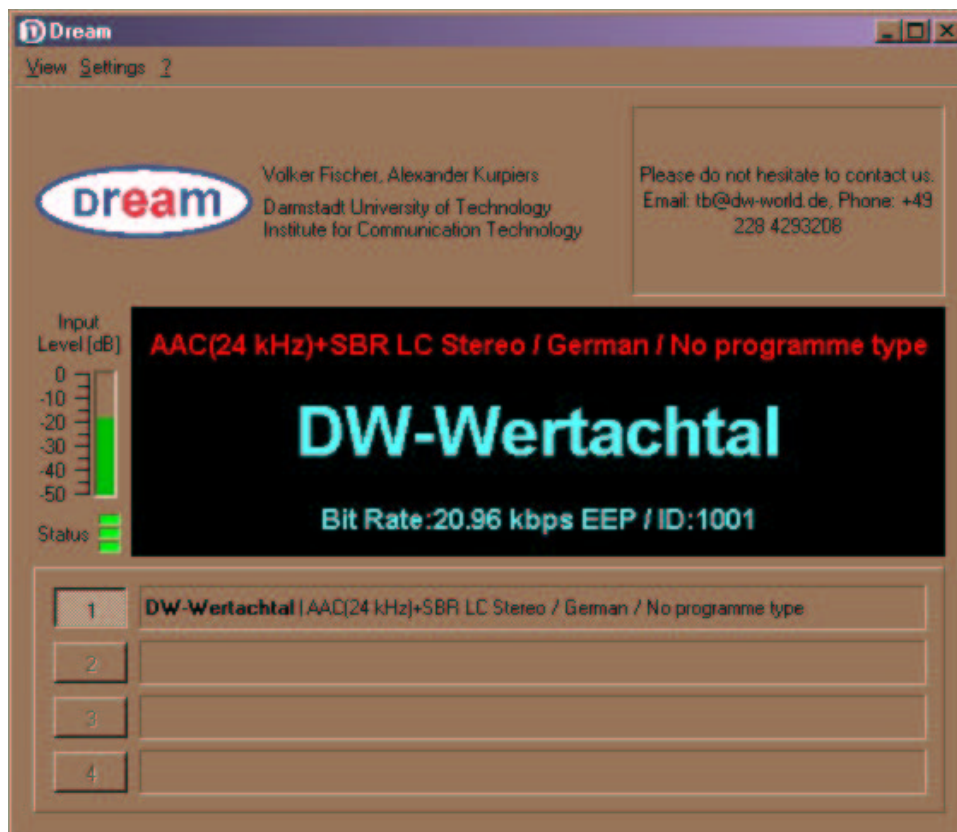

- **Text Message:** On the top right the text message label is shown. This label only appears when an actual text message is transmitted. If the current service does not transmit a text message, the label will be invisible.
- **Input Level:** The input level meter shows the relative input signal peak level in dB. If the level is too high, the meter turns from green to red. The red region should be avoided since overload causes distortions which degrade the reception performance. Too low levels should be avoided too, since in this case the Signal-to-Noise Ratio (SNR) degrades.
- **Status LEDs:** The three status LEDs show the current CRC status of the three logical channels of a DRM stream. These LEDs are the same as the top LEDs on the Evaluation Dialog (described later in this document).
- **Station Label and Info Display:** In the big label with the black background the station label and some other information about the current selected service is displayed. The red text on the top shows the audio compression format (e.g. AAC), the sample rate of the core coder without SBR (e.g. 24 kHz), if SBR is used and what audio mode is used (mono, stereo, LC-stereo ->

low-complexity or parametric stereo). In case SBR is used, the actual sample rate is twice the sample rate of the core AAC decoder. The next two types of information are the language and the program type of the service (e.g. German / News).

The big turquoise text in the middle is the station label. This label may appear later than the red text since this information is transmitted in a different logical channel of DRM.

The turquoise text on the bottom shows the bit-rate in kbits per second of the current selected service. The abbreviation EEP and UEP stands for Equal Error Protection and Unequal Error Protection. UEP is a feature of DRM for a graceful degradation of the decoded audio signal in case of a bad reception situation. UEP means that some parts of the audio is higher protected and some parts are lower protected. On the right the ID number connected with this service is shown.

- **Service Selectors:** In a DRM stream up to four services can be carried. The service type can either be audio, data or audio and data. If a data service is selected, the Multimedia Dialog will automatically show up. On the right of each service selection button a short description of the service is shown. If a service is an audio and data service, a "+ MM" is added to this text. If a service is an audio and data service and this service is selected, by opening the Multimedia Dialog, the data can be viewed while the audio is still playing.
- **View Menu:** In the view menu the Evaluation Dialog and the Multimedia Dialog can be opened.
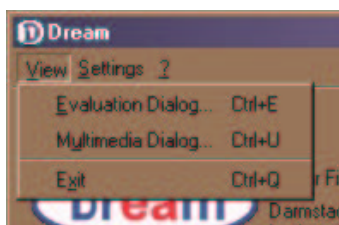
- **Settings Menu:** If more than one sound cards are installed in the system, the output and input sound card can be chosen (Only implemented in the Windows version of Dream). The Wave Mapper Playback / Recording are the default sound card devices selected by the operating system. If only one sound card is installed, both, the Wave Mapper and the actual sound card entry will appear. In this case, both menu entries will select the same sound card.

With the Receiver Mode menu, analog or digital mode can be selected. There are short-cuts for the different modes (Ctrl+D for digital, Ctrl+A for analog demodulation) which is especially useful for analog mode since the a new carrier acquisition can be started by simply pressing Ctrl+A.
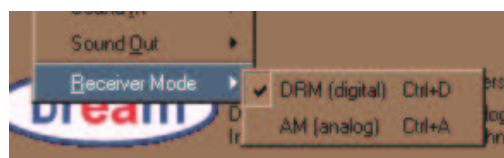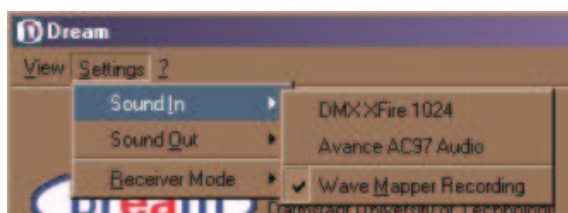
Evaluation Dialog

The Evaluation Dialog provides the user with detailed information about the current DRM reception. Some parameters like frequency offset or SNR estimation as well as some plots can be viewed here. Furthermore, advanced settings can be done.
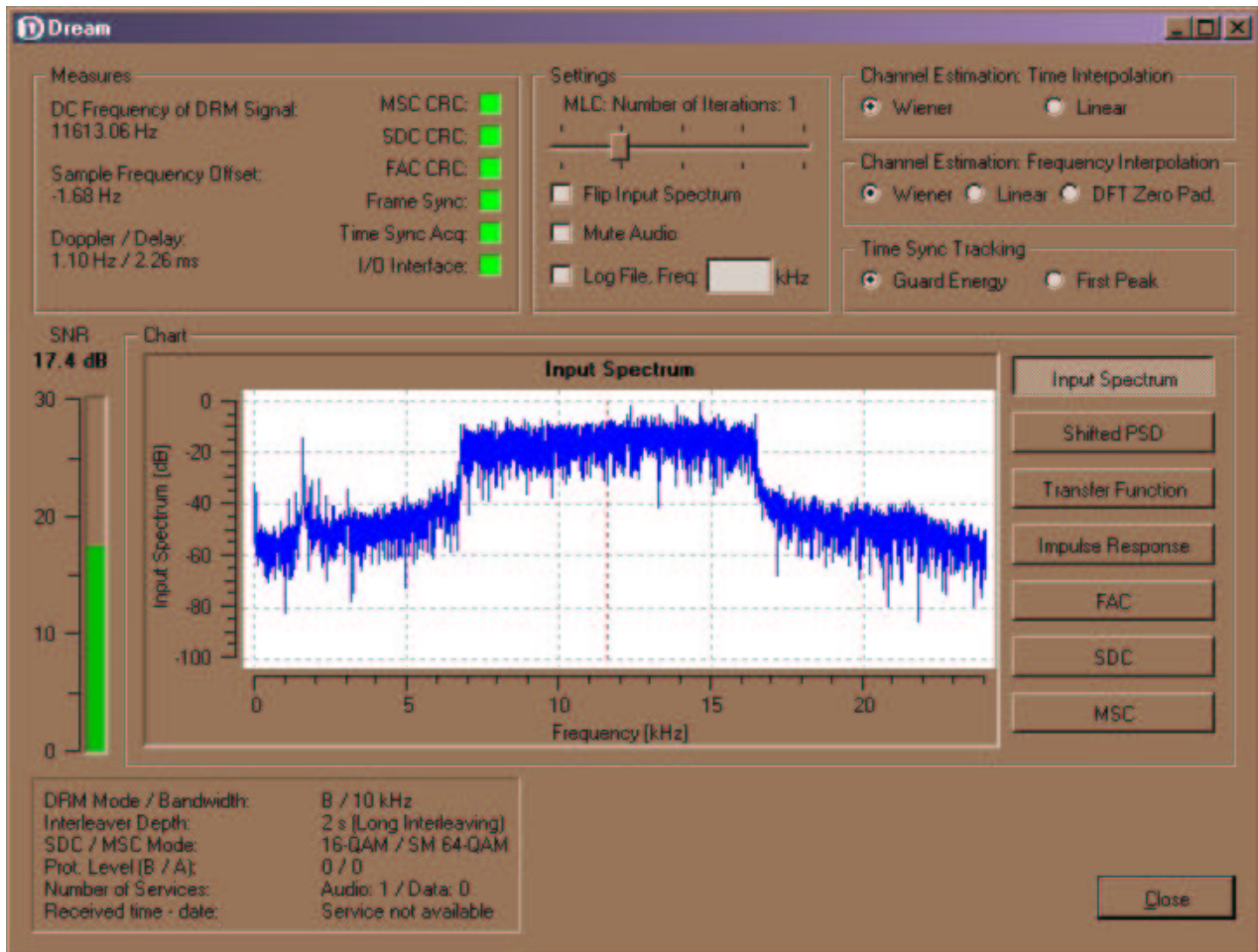
- **Measures Frame:**
  - ○ **DC Frequency Offset:** This is the estimation of the DC frequency offset. This offset corresponds to the resulting sound card intermedia frequency of the front-end. This frequency is not restricted to a certain value. The only restriction is that the DRM spectrum must be completely inside the bandwidth of the sound card.
  - ○ **Sample Frequency Offset:** This is the estimation of the sample rate offset between the sound card sample rate of the local computer and the sample rate of the D / A (digital to analog) converter in the transmitter. Usually the sample rate offset is very constant for a given sound card. Therefore it is useful to inform the Dream software about this value at application startup to increase the acquisition speed and reliability. This can be set with the command line arguments (described later).
  - ○ **Doppler / Delay:** The Doppler frequency of the channel is estimated for the Wiener filter design of channel estimation in time direction. If linear interpolation is set for channel estimation in time direction, this estimation is not updated. The Doppler frequency is an indication of how fast the channel varies with time. The higher the frequency, the faster the channel changes are.
    The total delay of the Power Delay Spectrum (PDS) is estimated from the impulse response estimation derived from the channel estimation. This delay corresponds to the range between the two vertical dashed black lines in the Impulse Response (IR) plot.
  - ○ **I / O Interface LED:** This LED shows the current status of the sound card interface. The yellow light shows that the audio output was corrected. Since the sample rate of the transmitter and local computer are different, from time to time the audio buffers will overflow or under run and a correction is necessary. When a correction occurs, a "click" sound can be heard. The red light shows that a buffer was lost in the sound card input stream. This can happen if a thread with a higher priority is at 100% and the Dream software cannot read the provided blocks fast enough. In this case, the Dream software will instantly loose the synchronization and has to re-synchronize. Another reason for red light is that the processor is to slow for running the Dream software.
  - ○ **Time Sync Acq LED:** This LED shows the state of the timing acquisition (search for the beginning of an OFDM symbol). If the acquisition is done, this LED will stay green.

- ○ **Frame Sync LED:** The DRM frame synchronization status is shown with this LED. This LED is also only active during acquisition state of the Dream receiver. In tracking mode, this LED is always green.
- ○ **FAC CRC LED:** This LED shows the Cyclic Redundancy Check (CRC) of the Fast Access Channel (FAC) of DRM. FAC is one of the three logical channels and is always modulated with a 4-QAM. If the FAC CRC check was successful, the receiver changes to tracking mode. The FAC LED is the indication whether the receiver is synchronized to a DRM transmission or not.
- ○ **SDC CRC LED:** This LED shows the CRC check result of the Service Description Channel (SDC) which is one logical channel of the DRM stream. This data is transmitted in approx. 1 second intervals and contains information about station label, audio and data format, etc. The error protection is normally lower than the protection of the FAC. Therefore this LED will turn to red earlier than the FAC LED in general.
- ○ **MSC CRC LED:** This LED shows the status of the Main Service Channel (MSC). This channel contains the actual audio and data bits. The LED shows the CRC check of the AAC core decoder. The SBR has a separate CRC, but this status is not shown with this LED. If SBR CRC is wrong but the AAC CRC is ok one can still hear something (of course, the high frequencies are not there in this case). If this LED turns red, interruptions of the audio are heard. The yellow light shows that only one 40 ms audio frame CRC was wrong. This causes usually no hearable artifacts.
- • **Settings Frame:**
  - ○ **MLC, Number of Iterations:** In DRM, a multilevel channel coder is used. Which this code it is possible to iterate the decoding process in the decoder to improve the decoding result. The more iterations are used the better the result will be. But switching to more iterations will increase the CPU load. Simulations showed that the first iteration (number of iterations = 1) gives the most improvement (approx. 1.5 dB at a BER of 10^{-4} on a Gaussian channel, Mode A, 10 kHz bandwidth). The improvement of the second iteration will be as small as 0.3 dB. The recommended number of iterations given in the DRM standard is one iteration (number of iterations = 1).
  - ○ **Flip Input Spectrum:** Checking this box will flip or invert the input spectrum. This is necessary if the mixer in the front-end uses the lower side band.
  - ○ **Mute Audio:** The audio can be muted by checking this box. The reaction of checking or unchecking this box is delayed by approx. 1 second due to the audio buffers.
  - ○ **Log File:** Checking this box brings the Dream software to write a log file about the current reception. Every minute the average SNR, number of correct decoded FAC and number of correct decoded MSC blocks are logged including some additional information, e.g. the station label and bit-rate. The log mechanism works only for audio services using AAC source coding. During the logging no Dream windows should be moved or re-sized. This can lead to incorrect log files (problem with QT timer implementation under Windows). This problem does not exist in the Linux version of Dream.
    The log file will be written in the directory were the Dream application was started and the name of this file is always *DreamLog.txt*
  - ○ **Freq:** In this edit control, the current selected frequency on the front-end can be specified. This frequency will be written into the log file.
- • **Channel Estimation and Time Sync Settings:** With these settings, the channel estimation method in time and frequency direction can be selected. The default values use the most powerful algorithms. For more detailed information about the estimation algorithms there are a lot of papers and books available.
  - ○ **Wiener:** Wiener interpolation method uses estimation of the statistics of the channel to design an optimal filter for noise reduction.
  - ○ **Linear:** Simple linear interpolation method to get the channel estimate. The real and imaginary parts of the estimated channel at the pilot positions are linearly interpolated. This algorithm causes the lowest CPU load but performs much worse than the Wiener interpolation at low SNRs
  - ○ **DFT Zero Pad:** Channel estimation method for the frequency direction using Discrete Fourier Transformation (DFT) to transform the channel estimation at the pilot positions to the time domain. There, a zero padding is applied to get a higher resolution in the frequency domain -> estimates at the data cells. This algorithm is very speed efficient but has problems at the edges of the OFDM spectrum due to the leakage effect.
  - ○ **Guard Energy:** Time synchronization tracking algorithm utilizes the estimation of the impulse response. This method tries to maximize the energy in the guard-interval to set the correct

timing.
- ○ **First Peak:** This algorithms searches for the first peak in the estimated impulse response and moves this peak to the beginning of the guard-interval (timing tracking algorithm).
- **SNR:** On the left side, the Signal to Noise Ratio (SNR) estimation is plotted as a bar and as a value.
- **Chart Frame:**
  - ○ **Input Spectrum:** This plot shows the Fast Fourier Transformation (FFT) of the input signal. This plot is active in both modes, analog and digital. There is no averaging applied. The screen shot of the Evaluation Dialog shows the significant shape of a DRM signal (almost rectangular). The dashed vertical line shows the estimated DC frequency. This line is very important for the analog AM demodulation. Each time a new carrier frequency is acquired, the red line shows the selected AM spectrum. If more than one AM spectrums are within the sound card frequency range, the strongest signal is chosen.
  - ○ **Shifted PSD:** This plot shows the estimated Power Spectrum Density (PSD) of the input signal. The DC frequency (red dashed vertical line) is fixed at 6 kHz. If the frequency offset acquisition was successful, the rectangular DRM spectrum should show up with a center frequency of 6 kHz. This plot represents the frequency synchronized OFDM spectrum. If the frequency synchronization was successful, the useful signal really shows up only inside the actual DRM bandwidth since the side loops have in this case only energy between the samples in the frequency domain. On the sample positions outside the actual DRM spectrum, the DRM signal has zero crossings because of the orthogonality. Therefore this spectrum represents NOT the actual spectrum but the "idealized" OFDM spectrum.
  - ○ **Transfer Function:** This plot shows the squared magnitude of the channel estimation at each sub carrier.
  - ○ **Impulse Response:** This plot shows the estimated Impulse Response (IR) of the channel based on the channel estimation. It is the averaged, Hamming Window weighted Fourier back transformation of the transfer function. The length of PDS estimation and time synchronization tracking is based on this function. The two red dashed vertical lines show the beginning and the end of the guard-interval. The two black dashed vertical lines show the estimated beginning and end of the PDS of the channel (derived from the averaged impulse response estimation). If the "First Peak" timing tracking method is chosen, a bound for peak estimation (horizontal dashed red line) is shown. Only peaks above this bound are used for timing estimation.
  - ○ **FAC, SDC, MSC:** The plots show the constellations of the FAC, SDC and MSC logical channel of the DRM stream. Depending on the current transmitter settings, the SDC and MSC can have 4-QAM, 16-QAM or 64-QAM modulation.
- **System Parameters Label:**
  - ○ **DRM Mode / Bandwidth:** In a DRM system, four possible robustness modes are defined to adapt the system to different channel conditions. According to the DRM standard:
    - Mode A: Gaussian channels, with minor fading
    - Mode B: Time and frequency selective channels, with longer delay spread
    - Mode C: As robustness mode B, but with higher Doppler spread
    - Mode D: As robustness mode B, but with severe delay and Doppler spread

    The bandwith is the gross bandwidth of the current DRM signal
  - ○ **Interleaver Depth:** The symbol interleaver depth can be either short (approx. 400 ms) or long (approx. 2 s). The longer the interleaver the better the channel decoder can correct errors from slow fading signals. But the longer the interleaver length the longer the delay until (after a re-synchronization) audio can be heard.
  - ○ **SDC / MSC Mode:** Shows the modulation type of the SDC and MSC channel. For the MSC channel, some hierarchical modes are defined which can provide a very strong protected service channel.
  - ○ **Prot. Level (B/A):** The error protection level of the channel coder. For 64-QAM, there are four protection levels defined in the DRM standard. Protection level 0 has the highest protection whereas level 4 has the lowest protection. The letters A and B are the names of the higher and lower protected parts of a DRM block when Unequal Error Protection (UEP) is used. If Equal Error Protection (EEP) is used, only the protection level of part B is valid.
  - ○ **Number of Services:** This shows the number of audio and data services transmitted in the DRM stream. The maximum number of streams is four.
  - ○ **Received time - date:** This label shows the received time and date in UTC. This information is carried in the SDC channel.

Multimedia Dialog

The multimedia dialog is capable of displaying the MOT Slideshow application. This is one possible data application of DRM.

The Receiving Status LED turns to green if the CRC of the current received data packet is ok. That does not mean that this data service is a MOT Slideshow service. It checks the CRC for all data services but only this specific service can be decoded.

If more than one slide show picture was received (and all received pictures are internally stored), with the four browser buttons the received pictures can be chosen. Pressing the left-most button jumps to the beginning. The next button jumps one picture back. The next button jumps to the next picture and the rightmost button jumps to the end of the list. If the end of the list is chosen, it will automatically be switched to the next received picture.

Pictures are only stored if the Multimedia Dialog is shown. If this dialog is closed, no pictures are received anymore.

With the file menu, either the current or all pictures can be saved. The pictures are always saved as the were received, no change to the format or compression is applied (maximum quality). If only one picture shall be saved, a file name must be specified. Otherwise a directory where all the pictures shall be stored to must be chosen.

Since some versions of QT cannot decode JPEG pictures, storing this picture is the only possibility for viewing it (with an external viewer application).

Command Line Arguments

The Dream application can be started with the following command line arguments:

```
-p, --flipspectrum  flip input spectrum
                    number of MLC iterations
-i , --mlciter      allowed range: 0...4
                    default: 1
-s , --sampleoff    sample rate offset initial value [Hz]
                    allowed range: -200.0...200.0
-m, --muteaudio     mute audio output
-f, --fromfile      disable sound card,
                    read from file instead
-h, -?, --help      this help text
```

The switches p, i, m are used to set the check boxes and leveler on the Evaluation Dialog to custom default values. This is useful if, e.g., a flipped spectrum is needed for a special front-end implementation. In this case an application link can be created using *drm -p* for starting the Dream software.

The f switch disables the sound input and reads from a file instead. This file must be located in a directory called *test* and the name of the file must be *TransmittedData.txt*. The data format must be

ASCII (48 kHz sample rate).
The initial value of the sample rate offset is useful to improve the acquisition performance of Dream. Since the sound card offset is usually very constant, the offset can once be estimated by the Dream software and then stored as the initial value. E.g., if the estimated sample rate offset is always -2.5 Hz, one can call the Dream software with *drm -s -2.5* to improve the performance.

AM demodulation

The AM demodulation implements a Single Side Band (SSB) AM demodulation. When the AM demodulation is chosen in the menu or Ctrl+A was pressed, the carrier frequency is estimated by a frequency domain algorithm. The signal in the range from this estimated frequency up to approx. 5 kHz above is cut by a spectral mask and shifted to the zero frequency. Therefore, only the Upper Side Band (USB) is used for demodulation. To demodulate the Lower Side Band (LSB), the Flip Input Spectrum switch can be used. In this case the whole spectrum is inverted and the AM demodulation algorithms uses the LSB.

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