dScope Series III Application Note

FM stereo multiplex (MPX) generation, including RDS data

Introduction

This application note describes how dScope's versatile signal generator can be programmed to produce an MPX stimulus (stereo multiplex) for testing FM radio receivers or transmitters.

The generated MPX has optional 50us or 75us pre-emphasis, and may also contain an RDS sub-carrier transmitting basic RDS data if required.

In the supplied example, a multi-tone stimulus is generated, with distinct left and right channel content, and analysis scripts are included to simultaneously measure channel balance, distortion and noise, high and low-frequency roll-off and cross-talk at the output of the equipment-under-test.

Since the dScope is programmed to fulfil this function using Visual Basic Scripting (VBScript) alone, it is easy for users to modify the supplied scripts to meet their particular requirements.

Quick start

The attached files should be copied to the following existing folder locations within the dScope installation directory (normally \Program Files\Prism Sound\dScope Series III\):

Copy contents of supplied folder…	… into installation directory folder
Configurations (File: mpxtest.dsc)	Configurations

User Wavetables
        (File: mpxtest.dss)
        (File: MPX.wfm)
	User Wavetables

Scripts\FFT Detector Calculations
        (Folder: MPX, containing:)
                (File: Balance.dss)
                (File: Cross-talk.dss)
                (File: LF Rolloff.dss)
                (File: HF Rolloff.dss)
                (File: TD+N.dss)
	Scripts\FFT Detector Calculations

The dScope should be connected to the receiver-under-test via an FM exciter as shown:
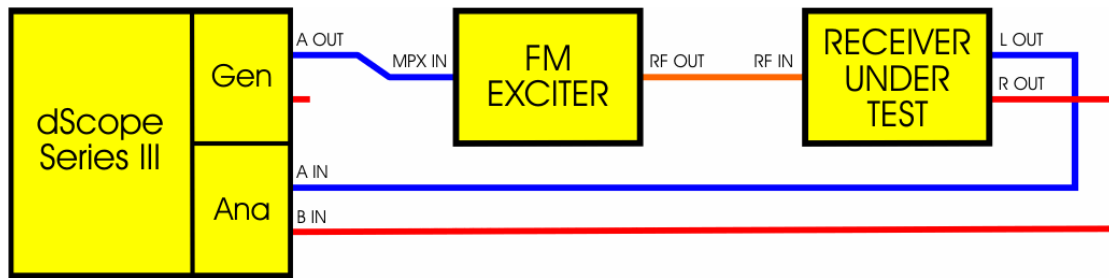
Run the dScope application, and load the configuration file:

      mpxtest.dsc

Ensure that the receiver is tuned to the same channel as the exciter. The exciter's input sensitivity should be adjusted to accommodate the dScope's MPX output level. If this is not possible, the dScope's output level can be modified by adjusting the output amplitude setting in the Signal Generator dialogue box.

The receiver should indicate that it is locked to a stereo transmission and, if RDS-enabled, should display the eight-character station identifier string, "PRISMRDS".

If the output of the receiver has a gain control, set it to the desired nominal position.

The dScope's Signal Analyzer should now simultaneously display the various measured parameters for each channel, as well as the recovered spectra, as shown below:
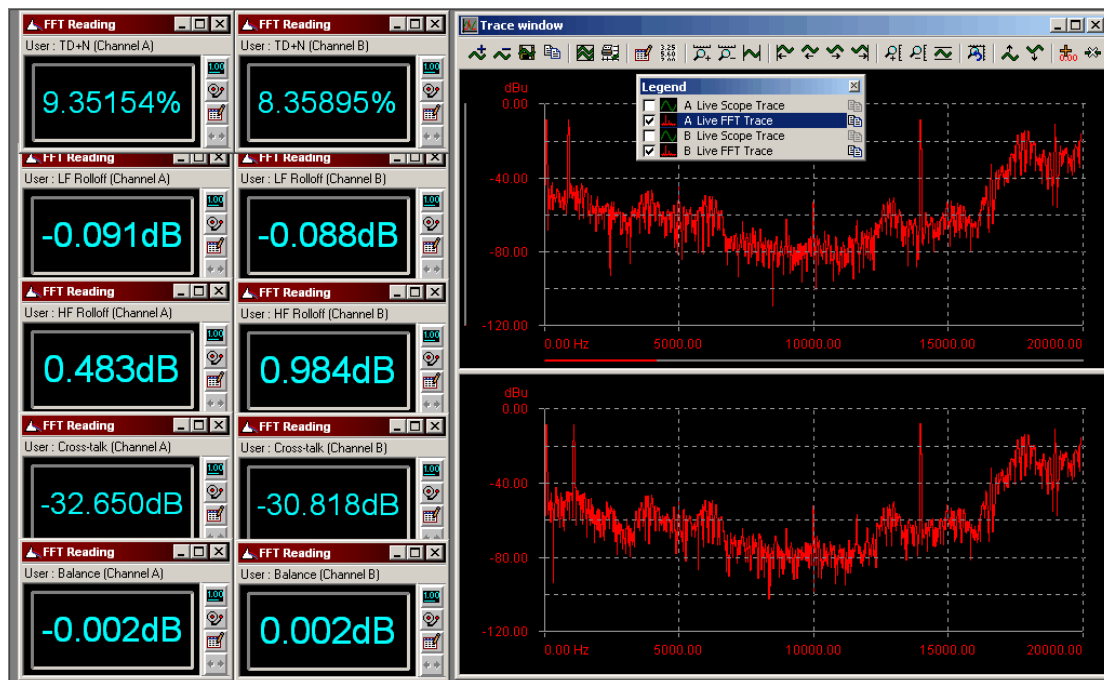
NOTE: Depending on the nature of the exciter, it may be necessary to place an attenuating pad between the exciter's output and the receiver's RF input. If so, this attenuator should match the output impedance of the exciter and the input impedance of the receiver (usually 75R). Some receivers incorporate an adjustable RF attenuator.

Troubleshooting

If the receiver does not recognise a stereo transmission, check the following:

- Is the dScope's A-channel analogue output connected to the exciter's MPX input?

- Is the exciter's RF output connected to the receiver's RF (antenna) input?

- Is the receiver set to the same RF channel as the exciter?

- Is the exciter switched on?

- Is the dScope application running, with the mpxtest.dsc configuration loaded?

- Is the input sensitivity of the exciter matched to the dScope output level?

- Is the RF output level of the exciter appropriate for direct injection into the receiver? You may need to use an in-line attenuator or adjust the RF input sensitivity of the receiver.

- Is the dScope generating the MPX signal correctly? You can check this by connecting the dScope's A-channel analogue output directly to one of the analogue inputs and examining the spectrum using the FFT Trace in the Trace Window. The spectrum of the MPX should look similar to this:

MPX spectrum at dScope output

- Is your dScope capable of analogue sampling at 192kHz? Some models aren't – check whether 192kHz sampling is selected in the Analogue Inputs dialogue box. If your dScope is not capable of analogue sampling at 192kHz, you can have it upgraded – contact your local distributor, or Prism Sound directly (sales@prismsound.com).

If the receiver recognises the stereo transmission, but the dScope Signal Analyzer does not receive a decoded multi-tone (as shown in the 'Quick Start' section above), check the following:

- Are the analogue outputs of the receiver connected to the analogue inputs of the dScope?

- If the outputs of the receiver have a volume control, is it turned up?

- Is the dScope application running, with the mpxtest.dsc configuration loaded?

- Is the dScope's FFT Analyzer trigger enabled (to enable, press the green-button icon on the main toolbar, tool-tipped: 'FFT Trigger On').

If the dScope Signal Analyzer receives a recognisable multi-tone, but the measurements are unexpectedly poor, check the following:

- Are the levels in the system well matched? The exciter input sensitivity must match the dScope output level to achieve a reasonable modulation depth and hence a reasonable signal-to-noise-ratio without excessive distortion. Similarly, if the receiver has a volume control acting on the outputs under test, this must be set to a reasonable level to maximise signal-to-noise-ratio and minimise distortion.

- Is the stereo separation poor? If the receiver is capable of good separation, it is possible that the limiting factor is the flatness of the frequency response of the exciter's input circuits – this can cause a compromise in stereo separation if the sensitivity at frequencies around the 38kHz sub-carrier is not identical to the base-band sensitivity, since opposite-channel cancellation in the L+R/L-R matrixing becomes inaccurate. It is possible to correct the separation for a non-flat exciter frequency response by varying the level of the 38kHz sub-carrier in the Generator Wavetable Script.

How it works

The dScope's signal generator is programmed to repetitively output a 192kHz-sampled wavetable representing the desired MPX stimulus, which has been calculated using a VBScript. The VBScript is supplied, and can be modified by the user as described in the following section.

In the supplied example, the MPX stimulus generated by the VBScript contains a three-tone multi-tone in each of the left and right channels. The frequencies of the tones are 70Hz, 900Hz and 14kHz in the left channel, and 70Hz, 1100Hz and 14kHz in the right channel. The amplitudes of the tones are equal, but they are pre-emphasized using the standard 50us emphasis filter. The mid-frequency tones are at different frequencies for the two channels to allow a cross-talk measurement to be made without varying the stimulus.

The three tones' samples are summed after pre-emphasis, then the sum of the left and right channel samples is included directly in the wavetable. Added to this is a 19kHz pilot tone and a 38kHz stereo sub-carrier, which is amplitude-modulated by the difference between the left and right channel tone samples. Optionally, an RDS sub-carrier at 57kHz is also added, which contains a complex digital bit-stream carrying basic RDS data, including an eight character station identifier string.

This multiplex is output from the A-channel analogue output of the dScope for input to an FM 'exciter' (modulator) whose output feeds the RF input of the receiver-under-test.

The stereo output from the receiver-under-test is input to the dScope's analogue inputs, and is sampled into a stereo buffer from which an FFT (spectrum) is calculated. A number of stereo 'FFT Detectors' are configured in the dScope's analyzer; each of these runs a custom VBScript on the FFT data every time a new buffer is acquired, and outputs a numerical result on the screen. Custom VBScripts are included to measure:

- TD+N: by summing all the bins between the recovered tones, and expressing this sum relative to the amplitude of the mid-frequency tone.

- LF Roll-off: by expressing the amplitude of the low-frequency tone relative to the amplitude of the mid-frequency tone.

- HF Roll-off: by expressing the amplitude of the low-frequency tone relative to the amplitude of the mid-frequency tone.

- Cross-talk: by expressing the amplitude of the mid-frequency tone leaked from the other channel relative to the amplitude of the mid-frequency tone in this channel.

- Balance: by expressing the amplitude of the mod-frequency tone relative to the amplitude of the mid-frequency tone in the other channel.

The results of these VBScripts are calculated and displayed for every buffer acquisition, so that all five stereo measurements are effectively made simultaneously on every pass.

Note that the generator VBScript only needs to be re-run if the user wishes to make modifications to the contents of the MPX stimulus. Otherwise, the existing wavetable may simply be loaded. Loading the mpxtest.dsc configuration file automatically loads the wavetable, as well as setting up the FFT Detectors, desktop etc.

User modifications

Both the Generator Wavetable Script (which defines the contents of the generated MPX) and the FFT Detector Calculation Scripts (which define the contents of the numerical 'FFT Detector' results) are easily modifiable by the user.

However, before undertaking script modifications, users should ensure that they have a good understanding of the principles of stereo FM radio transmission, as described in the 'Background' section below. In particular, modifications to the RDS data settings should be made with reference to standards documents EN50067 (Europe) or RBDS-1998 (US).

The Generator Wavetable Script is constructed to allow easy modification of parameters such as:

- Number of tones and tone frequencies;
- Pre-emphasis time constant;
- RDS sub-carrier enable/disable and RDS data contents;
- The relative amplitudes of the:
    - audio tones,
    - stereo sub-carrier,
    - stereo pilot tone, and
    - RDS sub-carrier;
- The default amplitude of the overall signal;

The operation of all parameters are documented within the script itself.

To make a modification, load the script "mpxtest.dss" in the User Wavetables folder into the dScope Script Edit window (using the Automation:Edit Script menu, then File:Open) and edit the appropriate parameters (these are generally located together at the head of the script). Run the script (don't forget to save it first), and then reload the resultant wavetable (MPX.wfm) into the generator by pulling down the Function drop-menu in the Signal Generator dialogue box and re-selecting 'User Wavetable".

Note that in the mpxtest.dsc configuration, the wavetable generation script is already loaded into the Script Edit window on page 5 of the dScope desktop.

Note that the Generator Wavetable Script may take some time to run (because of this, a progress bar is displayed whilst it completes). Most of this time is spent generating the RDS sub-carrier. For fastest execution, disable the RDS sub-carrier if it is not needed. If the RDS sub-carrier is enabled, run time can be shortened using the dRDSFilterTime parameter, which controls the accuracy of rendition of the filtered RDS modulation data, and thus at what level the skirts of the RDS sidebands impinge on the audio parts of the spectrum. The 5ms default is a good compromise, and will produce no noticeable audio degradation from the RDS data in most receivers. Increase the value (and hence the execution time) for better filtering, or reduce if the receiver quality is the limiting factor.

Modifications to FFT Detector Calculation Scripts can likewise be made by manually editing the desired script using the Script Edit window (the scripts are located in 'Scripts\FFT Detector Calculations\MPX'), re-saving it, and then re-selecting the Function as "User" in the appropriate FFT Detector window (there is no need to actually run the modified script – this is done automatically whenever the result is recalculated after each FFT analyzer buffer capture).

Stereo capability was added to FM radio broadcasting in the early 1960s, in a manner designed to be backward-compatible with mono receivers. To this end, the base-band mono signal is replaced with a summation of the left and right stereo channels, and an L-R difference signal is carried outside the base-band by amplitude-modulating a 38kHz sub-carrier. Note that, as in mono transmissions, the audio channels are pre-emphasised by boosting the higher frequencies, so that noise can be reduced at the receiver by HF attenuation. The time constant of the pre-emphasis filter is 75us in the US, and 50us in Europe and the rest of the world.

A 19kHz pilot tone is added to aid demodulation of the difference signal (since the 38kHz sub-carrier itself is suppressed) and to act as an indication of a stereo broadcast. Where RDS (Radio Data System) information is included, this is carried by adding a 57kHz sub-carrier which is amplitude-modulated by a complex modem-like signal carrying the robustly redundant RDS data stream.

The spectrum of the resultant multiplex is therefore organised like this:
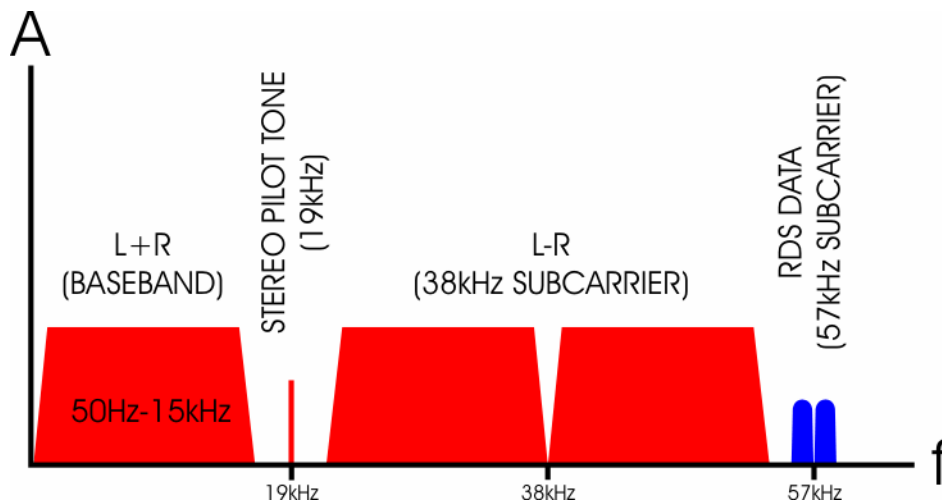
It is beyond the scope of this note to provide an exhaustive description of FM stereo broadcast technology, but a reasonable understanding may be required if the user wishes to modify the example scripts extensively. In that case, there are many good tutorials on the web, for example at:

http://en.wikipedia.org/wiki/FM_radio and

http://www.radio-electronics.com/info/broadcast/vhffm/vhf_fm.php

For more information about how RDS data is encoded on the RDS sub-carrier, see standards documents EN50067 (Europe) or RBDS-1998 (US).

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Technical queries should be emailed to tech.support@prismsound.com.