FFT AF Analysis with Modulation Analyzer FMA (or FMAB or FMB) and Option FMA-B8

Application Note 1EF06_1E

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Subject to change

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Products:

Modulation Analyzers of FMA Family

ROHDE&SCHWARZ

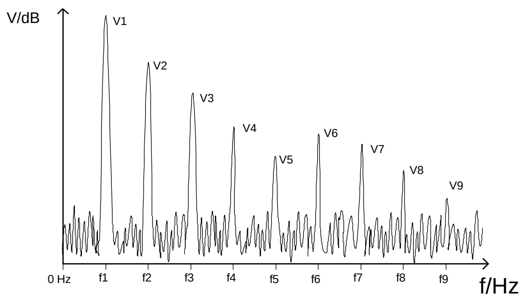
Introduction/Problems

The following frequency-selective measurements should be possible with the aid of the FMA (at the AF via voltmeter input or modulation distortion AM, FM, PM and FM stereo with Stereodecoder Option B3):

❒ Selective harmonic distortion and total harmonic distortion (d_i and d_n see **FIG. 1**),

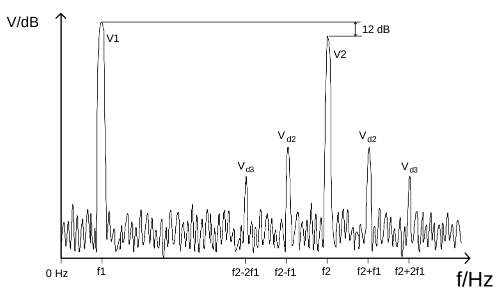
❒ Intermodulation distortion to DIN 45403 and IEC 268-2 (see **FIG. 2**), as well as

❒ Difference-frequency distortion DIN 45403 and IEC 268-2 (d_2 and d_3 see **FIG. 3**). A large variety of different high-precision filter functions which should preferably operate in parallel (for speed) is required. Graphic display of the spectrum would also be useful. The FMA, however, has no graphic display so that another form of visualization has to be found.



$$d_i = \frac{V_i}{\sqrt{\sum_{j=1}^{n} V_j^2}} \qquad d_n = \frac{\sqrt{\sum_{i=2}^{n} V_i^2}}{\sqrt{\sum_{j=1}^{n} V_j^2}}$$

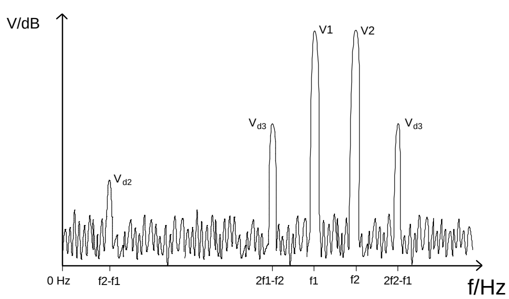
FIG. 1: Distortion measurement



$$d_2 = \frac{V(f_2 + f_1) + V(f_2 - f_1)}{V(f_2)}$$

$$d_3 = \frac{V(f_2 + 2 * f_1) + V(f_2 - 2 * f_1)}{V(f_2)}$$

FIG. 2: Measurement of intermodulation distortion to DIN 45403 and IEC 268-2



$$d_2 = \frac{V(f_2 - f_1)}{2 \cdot V(f_2)}$$

$$d_3 = \frac{V(2 \cdot f_2 - f_1) + V(2 \cdot f_1 - f_2)}{2 \cdot V(f_2)}$$

FIG. 3: Measurement of difference-frequency distortion to DIN 45403 and IEC 268-2

Problem Solution

The option FMA-B8 (AF Analyzer/DSP Unit), whose core is a high-speed signal processor (DSP56001; 25 MHz), allows the FMA to be extended to a test system for AF distortion, intermodulation distortion and difference-frequency distortion measurements. High measurement accuracy is achieved through digital processing using zoom FFT (see **FIG. 4** and **Table 1**)

The test results are output on two displays of the FMA and can also be polled via the IEC/IEEE bus. Another advantage is the output of the FFT spectrum with scaling as a vector graph to the two analog output channels of the module (DSP1⊖→ and DSP2⊖→). A simple analog oscilloscope operating in X-Y mode can be used to provide the FMA with a graphic display for representation of the FFT spectrum. In this way the quality of the applied signal can easily and quickly be checked and any additional interference (eg hum and noise or parasitic spectral lines) be recognized. Interpretation of the digital readings is also greatly facilitated. In addition to the spectrum, a simple grid is output which enables levels and frequencies to be immediately estimated or the display area to be adjusted to the screen grid of the oscilloscope. The required grid constants as well as the flat-top window coefficients and the rotation factors of the FFT are stored in an EPROM in the AF Analyzer/DSP Unit. Variable data as well as the DSP programs themselves (code) are loaded from the main processor of the FMA to allow quick and easy upgrades. Extended measurement capabilities can thus simply be implemented by a firmware update of the FMA (new flashup).

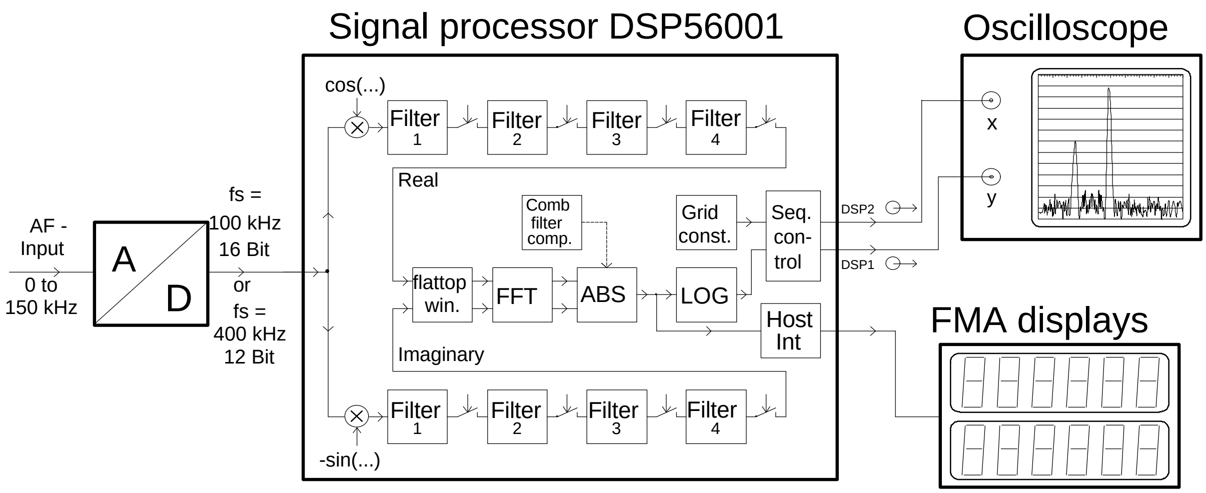


FIG. 4: Spectral analysis and AF measurement with FMA-B8

The excellent frequency resolution (min. 10 Hz) is achieved by special digital processing (zoom FFT → complex downconversion on algorithm basis + complex FFT, see **FIG. 4**). A frequency window of variable center frequency can thus be investigated. The resolution depends on the selected span. Several algorithms with different spans and resolutions are implemented (see **Table 1**). For certain measurements (eg measurement of difference-frequency distortion) a high frequency resolution in conjunction with a wide frequency range is required. It may then be necessary to shift the frequency window defined by the algorithm several times to obtain all spectral lines for the measured value. In this case only one window will be output to the oscilloscope since a fast alternation may only cause confusion. The main processor of the FMA always selects the optimum span according to a certain decision algorithm so that with the resolution required a maximum range can be investigated in one window.

Measurements are possible in a total range from 10 Hz to 150 kHz. This range is divided into two subranges: up 42 kHz the more accurate measurement mode is selected, in which the A/D converter uses a sampling rate of 97.656 kHz and 16 bits; above 42 kHz the instrument automatically sets the A/D converter to a sampling rate of 390.625 kHz with 12 bit resolution. In the 12-bit mode, the frequency response of the A/D converter must be corrected in the DSP (comb filter compensation). The measurement accuracy of the digital processor is somewhat lower in this case, since the frequency response of the comb filter can only be determined by approximation. The FMA can thus also be used as a simple FFT analyzer in the frequency range from 0 to 150 kHz.

The minimum measurement uncertainty is the result of an optimized FFT algorithm (approx. 23 bit resolution), pre-processing of the sampling values with a high-accuracy flat-top window (max. ripple 0.00245 dB) and the use of precision FIR filters.

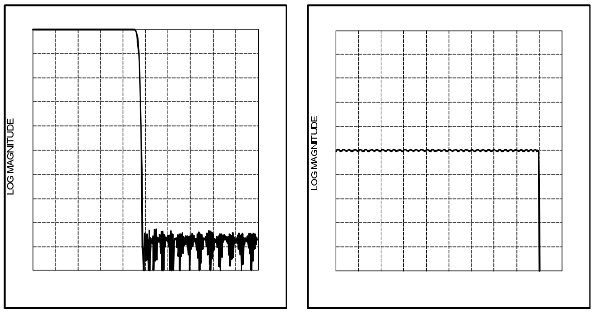


FIG. 4: FIR filters in complex processing

The oscilloscope display has a dynamic range from 0 to -132.5 dB (corresponding to 22 bit resolution). Vertical grid lines are output at a spacing of 10 dB, horizontal scaling is possible by means of a decimal ruler output at the zero line. The scaling in Hz/div depends on the selected span (see **Table 1**).

What is displayed on the oscilloscope?

The oscilloscope always displays the frequency spectrum window which is automatically selected by the FMA according to the test parameters defined. If several frequency windows are required to determine the result, only one window will be output, namely the one showing the signals of interest. The span results from the required resolution, which in turn is derived from the smallest spacing of the spectral lines. A set of discrete resolutions (and hence spans) is available in the instrument. The span is selected according to the principle of minimum requirement (the required resolution must just be reached).

16-bit mode, f_s=97.656 kHz

Span in Hz	Scaling in Hz/Div	Resolution in Hz	Accuracy in dB
490	49	8,5	0.003
1480	148	26	0.003
4920	492	85	0.003
14 000	1400	260	0.003
46 000	4600	800	0.003

12-bit mode, f_s=390.625 kHz

1600	160	29	0.03
15 000	1500	225	0.01
184 000	18 400	2700	0.01

Table 1: Available test programs

The specified accuracy refers to digital processing only; errors of analog components have to be added.

By varying the center frequency, the frequency window is adjusted to the input signals as follows:

- Distortion measurement:
  Display of the spectrum to the right of the fundamental (f_1) including the fundamental.
- Intermodulation distortion measurement:
  Display of the spectrum of the input signal with the higher frequency (f_2). The center frequency of the window is set to f_2.
- Difference-frequency distortion measurement:
  For measurement of d_3, the spectrum of the low-frequency mixture product (f_2-f_1) is displayed, whereas for measurement of d_2 the spectrum of the higher-frequency input signal (f_1) is displayed. The center frequency of the window is set to the respective frequencies stated. This differentiation is necessary for displaying interference products that are of interest.

To facilitate orientation in the displayed spectrum, the following information can be obtained via an information menu:

❍ Start frequency of frequency window

❍ Stop frequency of frequency window

❍ Scaling in Hz/div

The corners of the output grid must be adjusted to the corners of the oscilloscope grid.

Qualitative measurements on the oscilloscope can be made either via the output grid or via the grid of the oscilloscope.

The center frequency of the window is set with an accuracy of 1 mHz for all measurements. The only exception is the measurement above 42 kHz (if at least one of the spectral lines to be measured is above 42 kHz), since in this case the sampling rate of the A/D is increased to 390.625 kHz and the DSP therefore requires a higher computing power. In this case, the center frequency can only be adjusted in steps of 3052 Hz (span 15 kHz) or 1526 Hz (span 1.6 kHz). The host processor of the FMA then selects the lower center frequency in this quantized frequency raster.

Example of a test setup

Difference-frequency distortion measurement on sound broadcast transmitter

Due to the high complexity of the instrument (generator and analyzer integrated), the test setup is extremely simple (see **FIG. 6**).

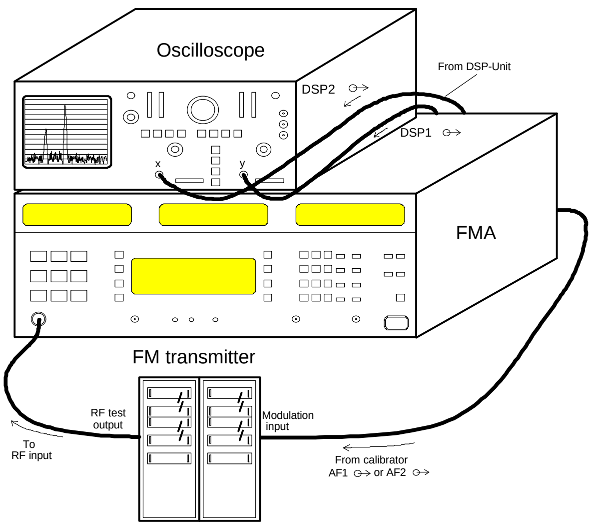


FIG. 5: Test setup with FMA

The device under test (eg an FM sound broadcast transmitter) is stimulated by signals from the calibrator/AF generator. The signal response can be applied to the DSP unit via the RF input (after FM demodulation and optional stereo decoding) for evaluation. For display of the spectrum, an oscilloscope must be connected to the two outputs of the DSP unit.

Operation

Thanks to a systematic menu control, the guidance through the menu levels is self-explanatory. The following settings can be made:

Setting the AF generator

First, the AF signal must be assigned to a physical output (eg AF1 ⊖→ or AF2 ⊖→). This is made in the following menu:

❍ CALIBRATE / GENERATOR / DESTINATION / AF output

The output impedance can also be adjusted within this menu.

Now the unit of the level entry can be selected under

❍ CALIBRATE / GENERATOR / UNITS

Finally, the two-tone generator must be activated.

❍ CALIBRATE / GENERATOR / AF
AF 1 and 2 can be individually switched on and off as well as frequency and level be assigned to them.

Setting the AF analyzer

Since the signal is applied to the RF input, the desired demodulation mode has first to be selected in the menu

❍ DEMOD

In our example FM has been selected.

The desired measurement mode can be selected now.

Measurement of the selective harmonic distortion is activated in the menu

❍ AUDIO / DIST SINAD / SELECTIV

Measurement of d_2, d_3, d_i and THD d_2 to d_n can be selected. Submenus are provided for adjusting i and n. Readout is either in % or dB and selected under

❍ AUDIO / DIST SINAD

Intermodulation and difference-frequency distortion measurement can be selected in the menu

❍ AUDIO / INTERMOD

MOD DIST has to be selected for measurement of intermodulation distortion and DIFF DIST for difference-frequency distortion. Either d_2 or d_3 can be indicated.

Further settings can be made under

❍ AUDIO / INTERMOD / UNIT

where readout in % or dB can be selected, or under

❍ AUDIO / INTERMOD / TUNE
If an external source is used, tune frequencies must be defined for AF 1 and 2. If the internal calibrator/AF generator is used, it is sufficient to select INTERNAL.

Measurement results

If all test parameters have been set as desired and an oscilloscope is connected to DSP1 ⊖→ and DSP2 ⊖→ , displays as shown in **FIGS. 7** and **8** are output on the screen.

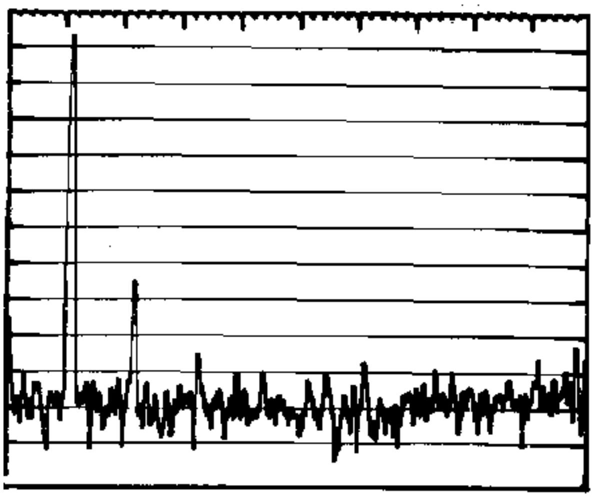


FIG. 6: Selective distortion measurement

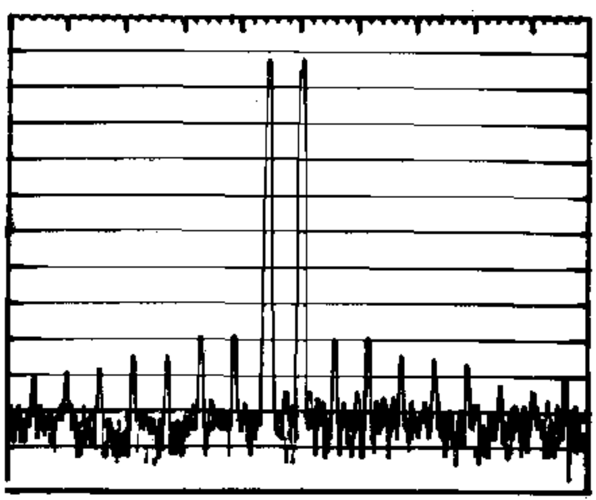


FIG. 7: Difference-frequency distortion measurement

Orientation in screen display

As already mentioned before, the start and stop frequency as well as the scaling in Hz/div of the displayed window can be obtained via an INFO menu. Vertical scaling in dB is possible with a spacing of 10 dB on the basis of the grid lines. If one also wants to know the resolution of the selected FFT or the span of the displayed spectrum, this information can be extracted from the horizontal resolution (Hz/div) in **Table 1**.

If the INFO menu for instance gives a grid scaling of 148 Hz/div, a FFT with a span of 1.48 kHz and a resolution of 26 Hz (with a theoretically assumed dynamic range 132.5 dB) has been selected.

Résumé

In conjunction with the optional AM-FM Calibrator/AF Generator FMA-B4 the Modulation Analyzers of the FMA family form complete and universal modulation test sets for transmitters and transposers. With the AF generator providing the required high-precision stimuli (single-tone, two-tone signals), the AF analyzer now provides comprehensive analysis facilities.

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