Measurement of AM Transmitters for Digital Audio Broadcasting

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Abstract *AM transmitters must satisfy some conditions to be employed for digital audio broadcasting. The goal of this work is to determine the relationship between intermodulation products on the transmitter output and the envelope and phase signals delay in case of complex modulating signals. The envelope signal path bandwidth is also observed.*

1. Introduction

Within several years a transition from analog to digital radio broadcasting can be expected in traditional AM bands below 30 MHz. The worldwide standard DRM (Digital Radio Mondiale), approved by IEC last year, was put through the test in many countries and revealed good technical features. Many broadcasters around the world have started DRM transmission. A transmission test lasting several days was also conducted on the MW transmitter Hradec Králové in the Czech Republic. Before the regular transmission starts a measuring of linearity of AM transmitters in use should be done to find out if the transmitters answer DRM needs. The DRM system is based on multiple carrier modulation OFDM and is defined as the functional block performing the adaptation of the data from MPEG audio encoder to the input of AM transmitter. One of its basic requirements is compatibility with existing AM services (channel spacing) and continued use already installed modern AM transmitters. Signal OFDM is a complex digital signal represented by I (in phase) and Q (quadrature phase) components. Resultant composite signal has simultaneous amplitude and phase modulation with a peak-to-average ratio (crest factor) about 10 dB. In order to linearly amplify OFDM signal by a nonlinear transmitter the envelope elimination and restoration (EER) technique has to be used. Cartesian I and Q components are converted into polar envelope A and phase φ components, envelope signal is applied to the transmitter's modulation input and phase signal modulates the phase of transmitter's carrier (see Fig. 1).

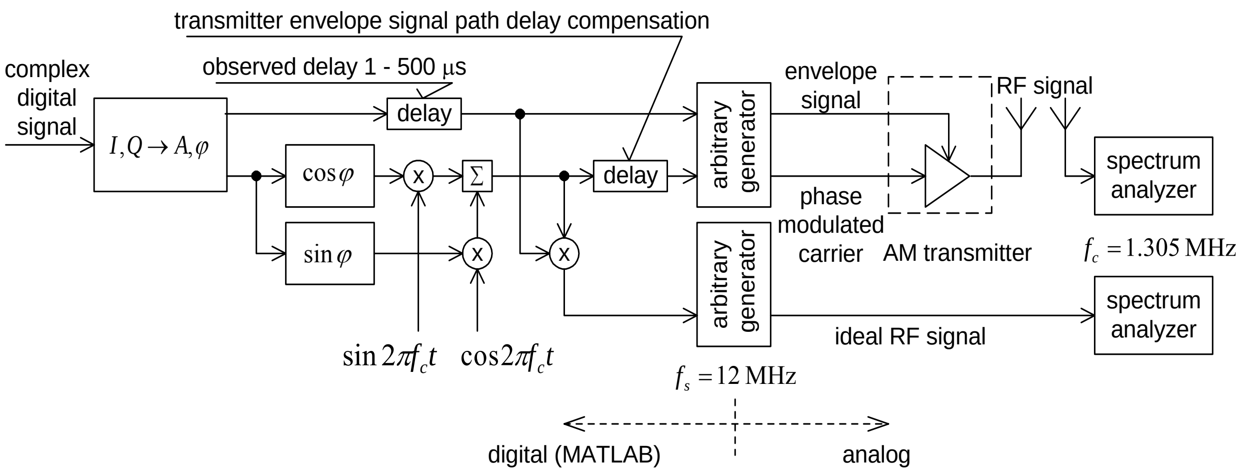

Fig. 1: Measurement block diagram

The coordinate transform is nonlinear and results in increasing of envelope and phase bandwidth compared to bandwidth of I and Q components. EER technique requires the envelope and phase modulated signals to be accurately combined within the transmitter power amplifier to produce the correct vector modulated waveform at the output of the transmitter. It depends first of all upon such parameters as the difference in the delay between the envelope and phase signal paths and the bandwidth of the envelope modulator.

2. Measurement configuration

The measuring of intermodulation distortion (IMD) is a traditional method of determining the linearity of transmitters. A single phase PDM transmitter (TESLA SRV1TR) with a switching frequency of 70 kHz was measured (carrier frequency $f_c = 1.305$ MHz). The envelope signal bandwidth (-3dB) could be selected either 10 kHz or 15 kHz. The goal of this work is to find out the relationship between IMD products on the transmitter output and the delay between the envelope and phase signals. Before the measuring started the difference in the delay between the envelope and phase signal paths was compensated by insertion of the delay into the modulated carrier signal path, envelope delay was set up from 1 μs to 500 μs.

Two types of the complex digital signal were chosen for this purpose. Firstly – the sum of two tones (AM SSB) and secondly – the OFDM signal similar to DRM system signal was generated. The envelope and phase of the both test signals were simulated in MATLAB and generated by a two-channel arbitrary waveform generator (sample frequency $f_s = 12$ MHz), as is shown in Fig. 1. To evaluate the results of transmitter measuring the RF signal (denoted as an ideal RF signal) was also computed in MATLAB and generated by an arbitrary waveform generator.

3. Two-tone sum measurement results

At first the sum of two-tone signals with frequencies 3.5 kHz and 4.5 kHz was used. The 4.5 kHz tone was selected as it represents the upper frequency of 9 kHz AM channel (as it is valid for the Czech Republic). On the one hand amplitudes of both tones was set equal and on the other hand one of them was set at level of 3 dB lower.
The results – third-order product level referenced to tone with higher amplitude (assigned as IMD suppression) were obtained from the spectra of RF output signal. In the case of ideal RF signal and delay 0 μs the spectrum consists of only two frequency tones. In the case of real RF signal even if delay is 0 μs the spectrum contains IMD higher-order products

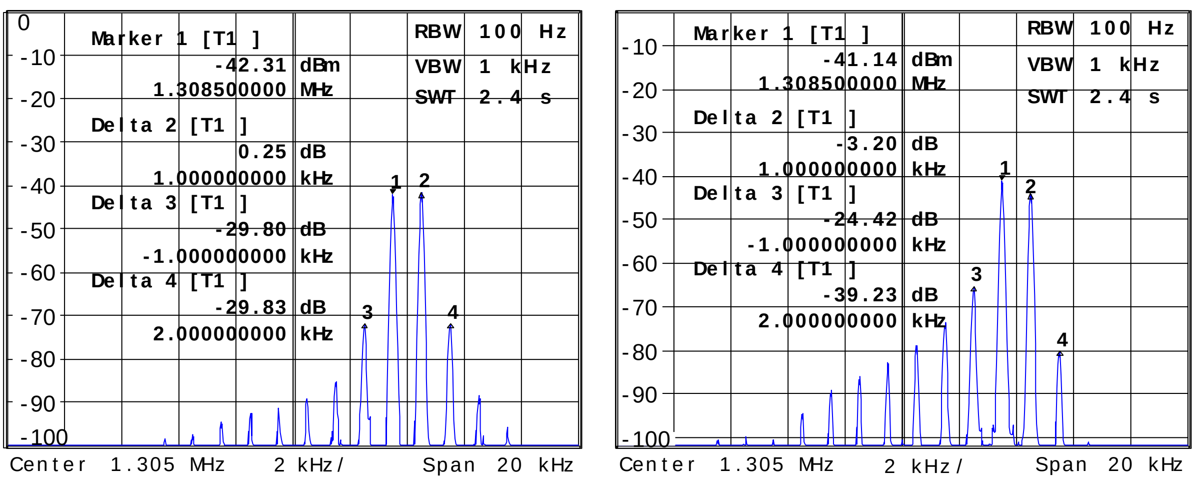

Fig. 2: The spectrum of the sum of two equal (on the left) and unequal (on the right) tones at the transmitter output (delay compensated)

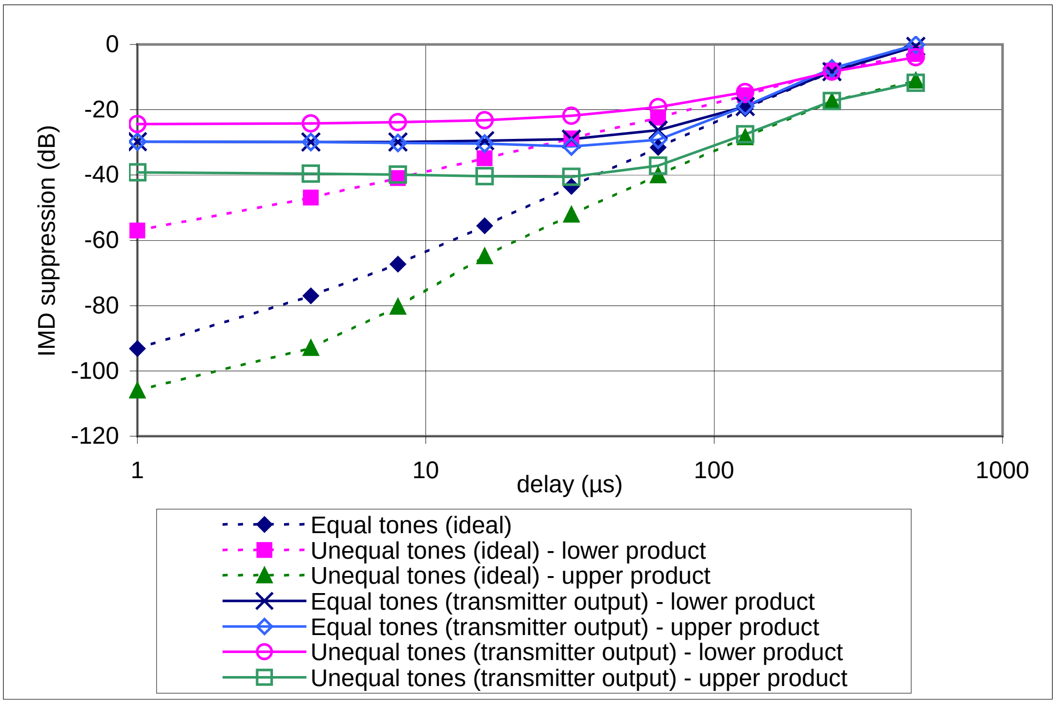

Fig. 3: IMD suppression as a function of delay between the envelope and phase signal

(as illustrates Fig. 2), because of a transmitter non-linearity. As an example in [1] IMD suppression of -30 dB (for military standard) and in [2] IMD suppression of -40 dB (for a good SSB system) is required. IMD suppression as a function of delay between the envelope and phase signal was measured and results are in the Fig. 3. Lot of two-tone measuring with different frequencies of tones separated by 1 kHz leading to IMD products appearance in the both lower and upper side bands ($f_c \pm 10$ kHz) was done for both envelope signal bandwidths. Differences in IMD suppression were irrelevant (about 1 dB).

4. OFDM signal measurement results

Secondly the OFDM signal without guard interval was computed. The number of 183 carriers was used leading to the bandwidth of 9 kHz. By the switching off 20 carriers the "hole" in the spectrum was obtained, so that the carrier to inter-carrier interference ratio (C/ICI) could be measured. Spectrum in the Fig. 4 shows C/ICI at the transmitter output for delay 8 µs. As the delay between the envelope and phase signal increased the bottom of the "hole" grown up. The results – C/ICI as a function of delay for the both envelope signal bandwidths (B_env) are shown in the Fig. 5. It is evident, that

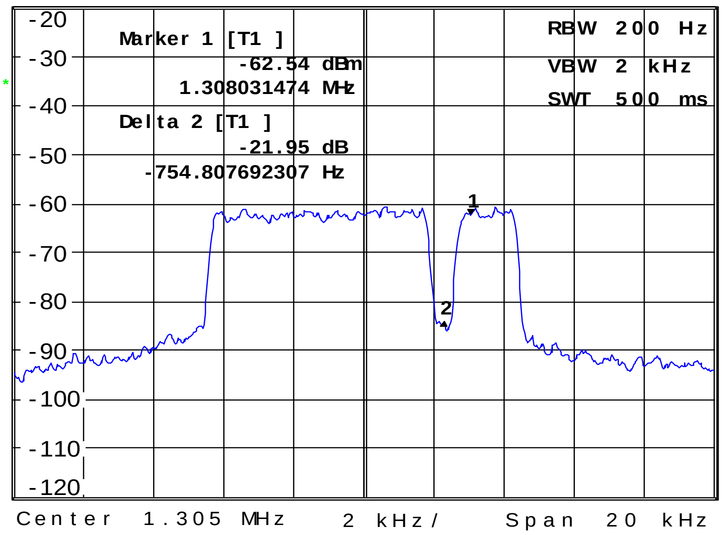

Fig. 4: C/ICI of the OFDM signal spectrum (the "hole")

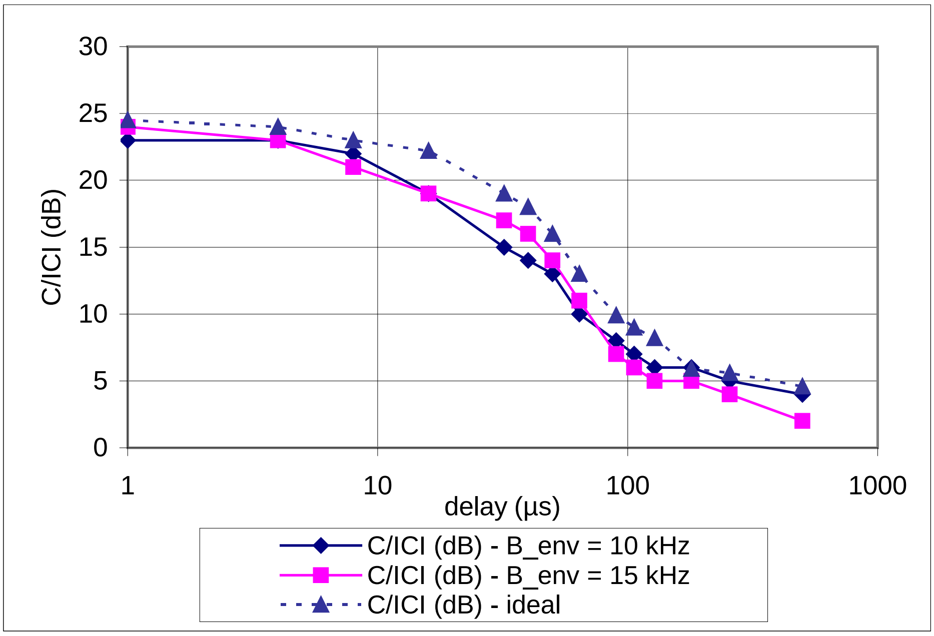

Fig. 5: C/ICI as a function of delay between the envelope and phase signal

influence of the B_env is negligible, because the "hole" is quite near to the central carrier (about 2 kHz) in relation to both B_env (10 kHz and 15 kHz).

5. Conclusion

Described measurements provide information about the performance capability of an AM transmitter to operate well with the signal of digital audio broadcasting system. The both types of used complex modulating signal seems to be suitable for determination and following compensation of delay between the envelope and phase signal paths. The best IMD suppression of -30 dB and the best C/ICI of 24 dB for delay 0 µs were obtained. Measurement results are influenced also by another transmitter non-linear behaviour, caused predominantly by quite low switching frequency of PDM modulator, mainly for small delay values. In the case of OFDM modulating signal with "hole" near by the central carrier this influence is not so evident. The envelope signal bandwidth is not so significant for the results contrary to delay. But the both delay and bandwidth strong influences the shoulder attenuation – measuring of this influence is further topic of our work.

Acknowledgement

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