On advanced transmitter and receiver models for the EMC analysis of modern communication systems

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Abstract

The comprehensive EMC analysis of communication systems includes, as fundamental basis, the physical layer of the signal transmission. It is pointed out in this contribution that it is also desirable to include in the context of modern communication systems the higher order data link layer as well. This, in turn, requires to connect traditional EMC models to the concepts of communication theory. The possibility and necessity of this connection is illustrated by the examples of a generic OFDM data link and a smart meter immunity test result.

1 Introduction

Modern communication systems often involve concepts that are beyond the ones of analog data transmission and additionally require digital signal processing [1]. These concepts ususally do not appear in classical EMC (Electromagnetic Compatibility) models, as in the ones outlined in [2, 3], for example, and the question appears whether it is possible or necessary to have these concepts included in an EMC analysis. Refering to the International Standards Organization / Open System Interconnection (ISO/OSI) layer model, as illustrated in Fig. 1, the question can be reformulated according to whether besides the physical layer 1 also the data link layer 2 can be included in an EMC analysis. Generally, this analysis encompasses transmitter, propagation, and receiver models. The propagation models typically are physical and described by transmission line or electromagnetic theory and the inclusion of digital signal processing mainly requires appropriate and advanced transmitter and receiver models.

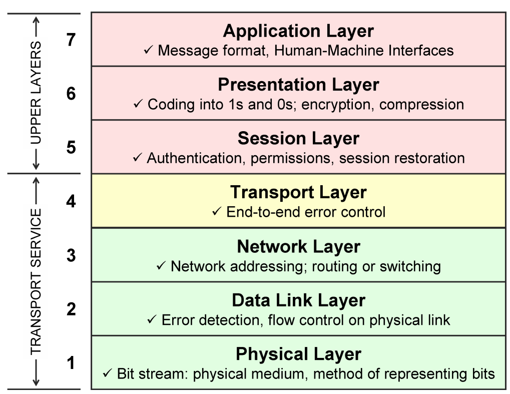

Figure 1: ISO/OSI layers which are used to describe digital communication systems by a hierarchical layer model [4]. The usual EMC analysis concerns the physical layer 1 which, in particular, contains the physical wired or wireless data connections. The data link layer 2 already involves advanced methods of digital signal processing and includes error detection and the digital elimination of unwanted signals, as possibly produced by EMI sources.

2 Traditional and advanced transmitter and receiver models

The notion of traditional transmitter and receiver models is not really well-defined but it can be stated that in view of the EMC of communication systems there are a number of established models which take into account properties such as the spectral content of a signal, the type of modulation used, the signal to noise ratio, the receiver bandwith

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and sensitivity, and so on [5]. Here, the different stages of data transmission are analog and, in the linear case, can be modelled by means of transfer functions, for example. To also include digital signal processing these established models have to be supplemented by processes such as analog-digital conversion, digital modulation, synchronization, and error detection, to name a few.

As an example for a digital transmitter and receiver configuration, in Fig. 2 a generic model of an Orthogonal Frequency Divison Multiplexing (OFDM) data link is shown. On the transmitter side, initial data words are mapped on a complex Quadrature Amplitude Modulation (QAM) plane and eventually modulated, digitally upconverted, and finally converted to the analog domain. On the receiver side, the incoming signal is converted back to the digital domain, digitally down-converted, demodulated and finally demapped on a complex QAM plane.

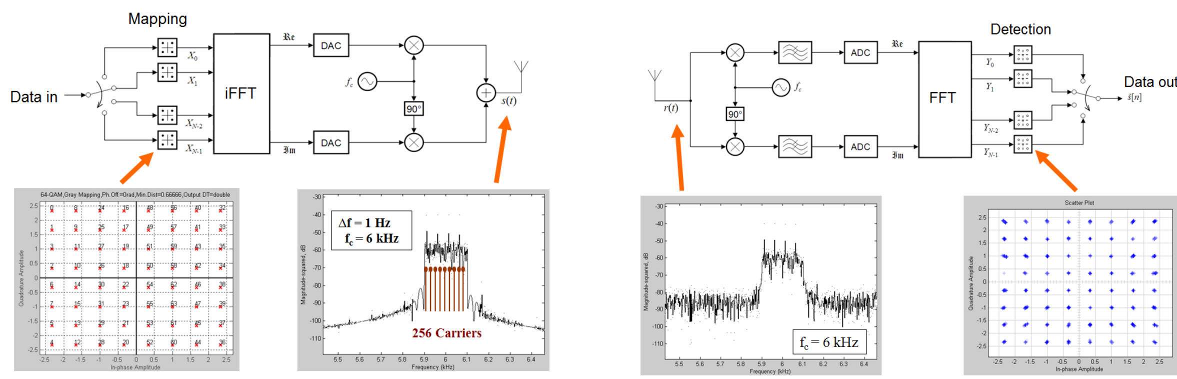

Figure 2: Transmitter and receiver configuration of a generic OFDM data link.

The single steps that are necessary to process the transmission and configuration can, in principle, be done analytically by hand, however, this is very cumbersome such that it is more feasible to implement the process in a software environment such as MATLAB/SIMULINK [6]. It is then possible to also add disturbing signals to the propagation channel and to investigate their influence on the received data words. In Fig. 3 the influence of some specific disturbances are shown and illustrated.

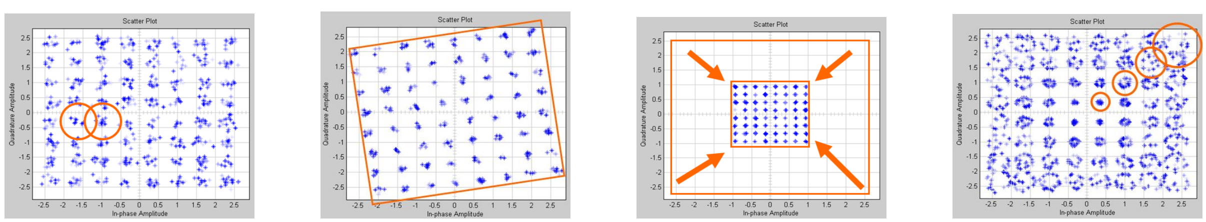

Figure 3: Resulting data word sets, obtained under the influence of, from left to right: (i) noise, (ii) phase shift, (iii) damping, and (iv) multipath effects. It is noted that the data link model does not include synchronization and error correction.

3 Examples

3.1 Symbol error rate of a generic OFDM data link

A transmitter and receiver configuration as shown above can be used, for example along the lines of [7, 8, 9], to study the symbol error rate (SER) in dependency of various disturbances. For a generic OFDM data link a number of parameters have to be set. These concern the different simulation blocks where modulation/demodulation, up-/down-conversion, and DA-/AD-conversion take place. For a fixed setting, Fig. 4 shows the SER in dependency of different parameters of a damped sinusoidal pulse which affects the propagation paths. The SER increases with increasing pulse amplitude and peaks at a pulse carrier frequency of about 1 MHz which corresponds to a passband frequency of the transmitter.

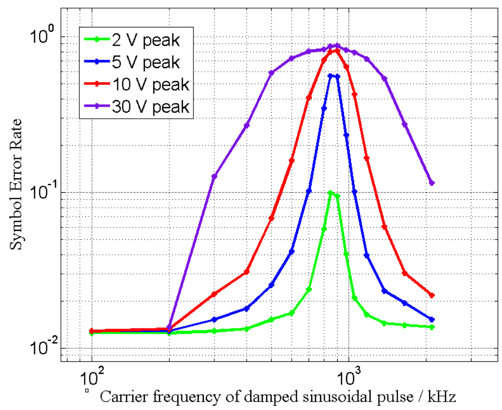

Figure 4: Illustration of a Symbol Error Rate in dependency of specific damped sinusoidal pulses that separately act as disturbances. The Symbol Error Rate refers to a generic OFDM data link.

3.2 Aliasing effects and smart meter immunity

In this section no data link but the practical example of an actual electricity meter test is considered. The electricity meter is a "smart" one, that is, the voltage and current signals are directly converted into the digital domain where they are further processed. The actual smart meter happened to pass the prescribed EMC tests but nevertheless failed in an enviroment which was subject to considerable disturbances in the frequency range 2–150 kHz. Therefore an immunity test was applied to the smart meter which followed a setup that is illustrated in Fig. 5. The test was done in frequency domain with a rather small frequency spacing of 0.4 %. The test result is shown in Fig. 5 as well.

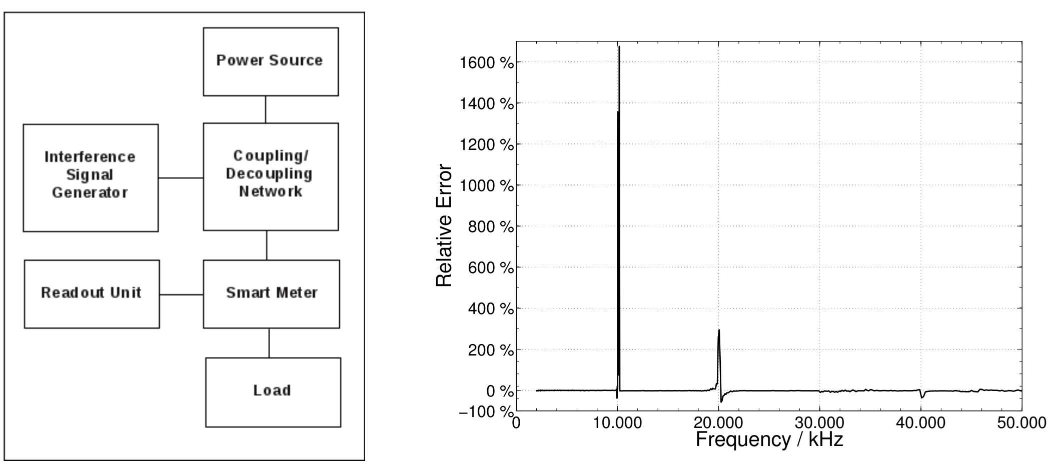

Figure 5: Immunity test setup of a smart meter device and test result.

It can be recognized that the smart meter exhibits a sharp and narrowband susceptibility at a frequency of 10 kHz and a second, less pronounced susceptibility at a frequency of 20 kHz. The reason for these susceptibilities were traced back to aliasing effects that are connected to a sampling frequency of 10 kHz. It is well known that, due to aliasing, disturbing frequencies close to the sampling frequency can appear as low frequencies, that is, with a sampling frequency of 10 kHz a disturbing frequency of 9.95 kHz can appear as a 50 Hz signal that is recorded by the smart meter and leads to an erroneous power measurement. The lesson that is learned from this example is that the smart meter should be seen as a digital receiver rather than a physical EMC victim. This is because the narrowband susceptibility can only be understood by the high-to-low-frequency conversion that is due to aliasing. It is not related to a physical narrowband resonance phenomenon. This, in turn, is important in order to correctly set up an EMC immunity test in frequency domain, e.g., with sufficient fine frequency spacing, since many standards presuppose that the test is performed within the physical resonance region of the device under test and set the test parameters accordingly [10].

4 Concluding remarks

EMC models of modern communication systems require to go beyond the physical layer and to also include the digital signal processing involved. It is, however, not immediate to combine the physical models with the models of communication theory. Digital communication links can be accomodated in simulation models where previously calculated physical disturbances can be taken into account. This has been exemplified by the model of a generic OFDM data link which is subject to damped sinusoidal pulses. The example of a smart meter immunity test has shown that classical EMC tests should take into account digital properties of devices under test for a meaningful interpretation of test parameters and test results.

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