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HF signals behaviour analysis

***Abstract**. The paper presents a set of simulations and measurements aiming to analyze the behavior of information-carrying disturbed signals and to further these studies regarding construction materials for intelligent buildings. Construction material shields must allow mobile phone carrier signals to pass through unaffected and also other household signals such as the one generated by a router within strict boundaries. Using the environment provided by Matlab's Simulink were recreated the actual conditions of indoor mobile phone call and a wireless data transmission. Using the same channel conditions, have been investigated the disturbances on GSM and WI-FI signals. As a follow up to these simulations, measurements have been conducted using different building material samples and suitable combinations of materials*

***Streszczenie.** Artykuł przedstawia wyniki symulacji i pomiaru propagacji zmodulowanych sygnałów systemów GSM i Wi-Fi poprzez ściany budynków inteligentnych zbudowanych z różnych materiałów konstrukcyjnych. Symulacja została wykonana w środowisku Matlab Simulink i odpowiada rzeczywistym warunkom propagacji sygnałów radiowych mobilnych systemów „indoor". (**Analiza zachowania się sygnałów w.cz.**).*

Keywords: simulation, measurement, materials, signals.
Słowa kluczowe: symulacja, pomiar, materiały, sygnały.

Introduction

High-frequency signals are increasingly used worldwide by various technologies and applications especially in the field of telecommunications where the mobile phone networks and the wireless environment in computer systems are experiencing an accelerated development.

The aim of this paper is to perform a set of simulations and measurements in order to study the behavior of different carrier signals passing through various construction materials. The set of simulations provides a general view on the behavior of different signals passing through channels of the same type. The study is based on two types of signals, the GSM 900 and the 802.11g WI-FI signal. These signals are frequently encountered in modern household environment, which determined the need to limit their area of influence. The behavior of the two types of signals will be compared during simulated propagation under similar conditions in order to observe their theoretical susceptibility to various stimuli.

Model description

The model description for GSM and OFDM is given in Fig. 1, respectively in Fig. 2. For the WI-FI model, the obtained error rate was 44.334%. For the GSM model, the obtained error rate was 9%. For the GSM system, the alterations introduced by the channels can be observed at waveform level. As expected, the signal is altered especially in terms of amplitude while its phase shift can be observed as well. Fig. 3 shows a portion of the GMSK and WI-FI signal after its passage through the channel.

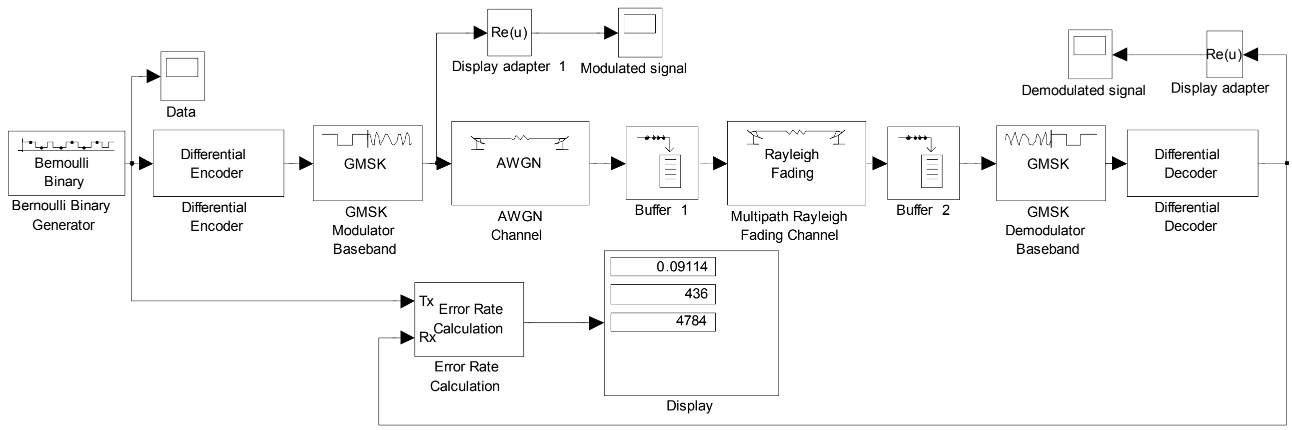

Fig. 1. GSM Model

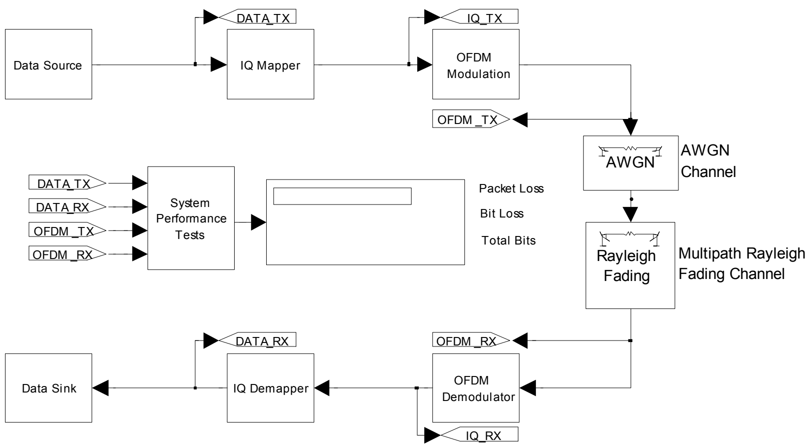

Fig. 2. OFDM Model

In the case of the WI-FI model, in order to effectively visualize the alterations produced to the signal, a spectral probe was employed signal's passage through the channel.

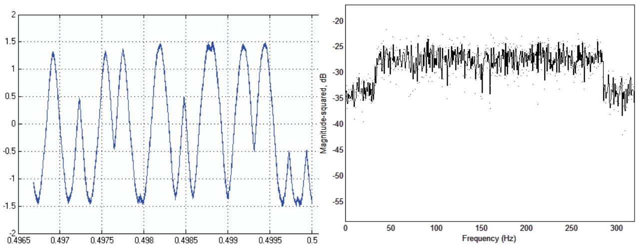

Fig. 3. GMSK respectively WI-FI signal after its passage through the channel

The most obvious effect of the channel, in this case, is the occurrence of noise within the signal spectrum. However, a phenomenon that escapes observation within one single frame is the signal's continuous variation, with is caused by the fading effect.

In order to detect the differences of amplitude and phase between the signals, the constellation diagram for the QAM demodulator was used. Again, the phenomenon could not be illustrated completely since the diagram varies continuously, but the high degree of signal distortion can be easily observed. Departing from these results, a detailed analysis was performed regarding the phenomena that are perturbing the two types of signals.

The analysis of the effects of the AWGN channel

At first we tested the functioning of the GSM signal using a single channel type, the one which introduces additive Gaussian white noise. The value of the signal-to-noise ratio used initially to test the model was 30dB. This value corresponds to a ratio of 1mW noise to 1W signal. As expected, no signal amplitude fluctuations could be observed but the signal distortion corresponds with the adopted signal-to-noise ratio. Using the Error Rate Calculation block, we found out that this noise level did not affect the transmitted data, none of the transmitted bits being affected, which yielded an error rate of 0%.

For a more thorough testing of the signal's resilience, two further tests were conducted. The first one used a 20dB signal-to-noise ratio. This corresponds with a ratio of 10mW noise to 1 W signal.

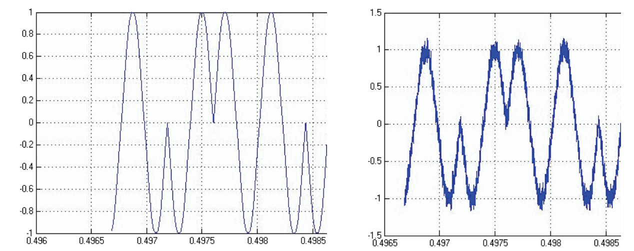

Fig. 4. The original signal and the perturbed signal with 20dB SNR

Figure 4 shows a significant increase of signal distortion compared to the previous case. In terms of error rate, the results are similar both having an error rate of 0%. In order to formulate a final conclusion about the effects of white noise on this type of signal, the test was repeated using a 10dB signal-to-noise ratio. This corresponds with a 10mW noise to 1W signal ratio. At the output of the AWGN block, the signal is heavily distorted but its overall waveform is preserved. Again, this is illustrated by the value of the error rate. Even for this high distortion level the latter stays 0%. Consequently, we can conclude that for this particular technique, the AWGN channel has no influence on the quality of the received signal. This is one of the reasons which justify the usefulness of this technique for GSM communications. With respect to the model of the WI-FI signal we first considered the 30dB signal - to-noise ratio, which had been used initially.

The constellation is heavily affected by white noise through the channel. In terms of error rate, the results show a dramatic difference compared to those obtained for the GSM signal. Thus, the obtained error rate was 14.32%. The before and after perturbation signal spectrum can be observed in Fig. 5. When increasing the signal-to-noise ratio to a value of 20dB a decrease of quality of the received signal can be observed. Under these conditions the obtained error rate was 37%. In order to verify the method used for the GSM signal, a test was conducted with a signal-to-noise ratio of 10dB. In this case the error rate is 46%. Compared to the previous case, the error rate increase is irrelevant but still unacceptable for practical proposes.

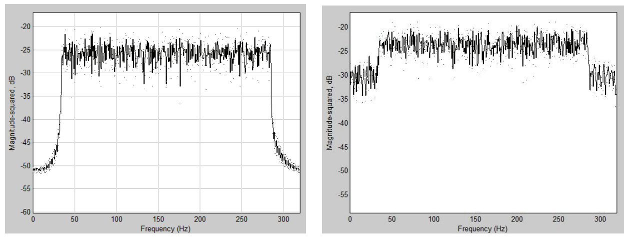

Fig. 5. The spectra of the original signal and of the perturbed signal with 30dB SNR

In conclusion to the simulations scenario, it can be observed that the GSM signal is more resilient to perturbations produced by white noise. Remarkably the effects of this type of noise are more important on the WI-FI signal spectrum. Regarding the quality of the transmission affected by white noise, this type of signal evolves satisfactory. The error rate obtained for the case of a noise-drowned signal is acceptable. At the same time, this result illustrates the property of frequency-scattered signal to reject wide band noise.

The analysis of the effects of multipath Rayleigh fading channel

In order to highlight the importance of fading in the case of total signal perturbation the AWGN channel was extracted from the two models. The first tests were conducted with the GSM model. After having performed the simulation the error rate was 9%. Due to the negligible influence of the AWGN channel, these are precisely the results obtained when using both channels. By using this case as reference scenario, it was attempted to observe the importance of every phenomenon introduced by the multipath Rayleigh fading channel.

The first tested factor was the Doppler effect. For the reference scenario this required a maximum frequency of 3.36 Hz corresponding to a traveling velocity of 40 km/h. This velocity was chosen in order to simulate an average of the velocities at which a telephone conversation takes place. To further test the effects of this phenomenon, the frequency was set to 0.36 Hz. This corresponds to a velocity of 4 km/h, which represents the average walking speed of a person. Under these circumstances, the obtained error rate was 6%. Consequently, a significant decrease of the error rate was observed, if the traveling velocity is reduced by a factor of 1/10. Remarkably, during simulation, the effect showed progressive characteristics. In accord with the previous scenario, this progressiveness is absent over its initial portion but becomes more obvious toward the final part of the transmitted sequence of bits. The signal cannot be observed on a large scale like in the previous scenario, but it can be viewed at the level of every transmitted symbol.

With respect to the WI-FI model, the testing of the various characteristic frequencies appears irrelevant since this system was not designed to operate on mobile stations moving at high velocities. Thus, only the scenario with the 0.02Hz frequency can be considered. In this case the obtained error rate was 40%. This leads to the conclusion that the fading phenomenon significantly affects the WI-FI signal.

Another important factor which must be considered is the operating mode of the multipath Rayleigh fading channel which simulates the multipath propagation in close connection with the Doppler effect. It can be even said, that in term of the block's operation, the two phenomena are interdependent. Thus, each model will use the frequencies introduced by the Doppler effect in accordance with the original scenarios.

As a conclusion to the results obtained after applying this signal battery of tests to the WI-FI model, we ascertained the fact that the signal is heavily affected by fading. After comparing the obtained results with the initial ones it was found out that by introducing multiple propagation paths the fading channel will produce an error rate that is similar to the case of a direct path between transmitter and receiver plus white noise.

Experimental determinations

The simulations of the behavior of the two studied signals allow the conclusion that the perturbations affecting the signal of a wireless network have a negligible effect on the GSM signal. Various tests were conducted on the attenuation of the WI-FI signal passing through different shielding materials. Several combinations of construction materials and nanomaterials were used in order to explore the possibility of controlled limitation of signal propagation. This possibility could be of practical importance for any type of environment, household or industrial both in terms of safety as well as electromagnetic compatibility. The measurements were conducted both indoors as well as outdoors while the influence of other perturbing factors on these environments was maintained low as possible.

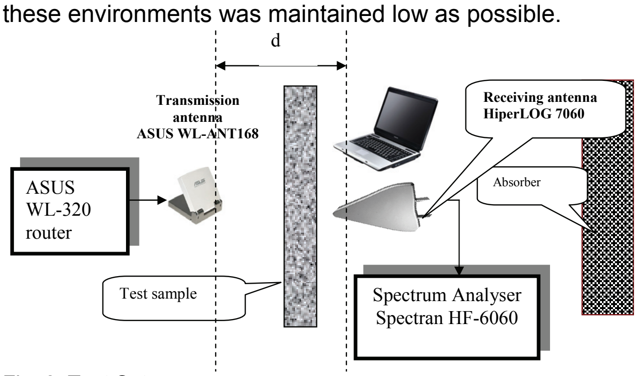

Fig. 6. Test Setup.

The first set of measurements was conducted on the behavior of the WI-FI signal inside a building. The structure of the room where the measurements were conducted is a standard apartment structure with concrete walls. Under such circumstance, the wave reflections from the room walls had to be considered.

The results obtained for different combinations are given in Fig. 7 [6].

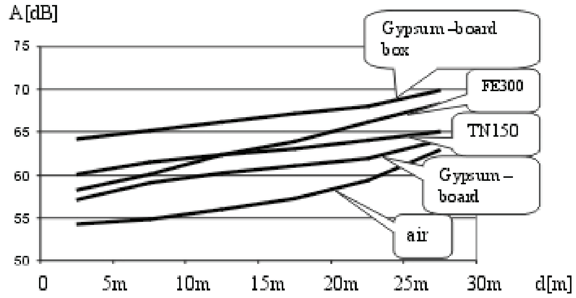

Fig. 7. Variation of attenuation depending on distance d measured with the spectrum analyzer.

Conclusions

The simulation models provide an overview on the behavior of the two high frequency signals the GSM and the WI-FI signal, respectively. The response of these signals to various stimuli during their propagation was investigated. As a final result, a much higher resilience of the GSM signal to the introduced interferences could be observed. Its response was characterized by a much lower error rate compared to the WI-FI signal, both being subjected to similar interferences. Hence, it results the conclusion that an environment which limits the propagation of the WI-FI signal has no negative effect on the GSM signal. Based on this information, the experimental study on the reduction of the WI-FI signal coverage area can be continued without the problem of affecting the GSM signal. In order to observe the behavior of the antennae for different levels of signal, the minimum and maximum emitting power levels were used. The attenuations measured with the spectrum analyzer differ from those obtained through the notebook software since the measuring system of the notebook only provides an estimative attenuation, but remarkably, the attenuation values for different materials referred to air attenuation are preserved. It can be appreciated that the shielding provided by the tested (low conductive) nanomaterials or by a gypsum board panel (10-20 mm thickness) is too low to provide adequate electromagnetic shielding of an apartment. An efficient shielding requires a stratified material or nanomaterials with a higher conductivity.

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