SIMULATING MULTIPATH PROPAGATION EFFECTS ON THE FM RADIO SIGNALS

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***Abstract*— Frequency modulated radio is the most widespread radio broadcasting method. The radio broadcasting companies spend a lot of money for using frequency band, that is why the National Media and Telecommunication Authority has responsibility to protect these frequency bands from unwanted noise. One of these noise source is the neighbouring station interference. The first problem is how to measure the deviation maximum without any reference signal, the second is how to eliminate the multipath propagation, which causes measurement errors. The scenario gives a possible solution, how to make a good model of simulation.**

I. Introduction

The frequency modulated radio broadcasting was invented in the first half of the twentieth century by Edwin Howard Armstrong[1]. Then become the second and most popular analog modulation technology. Against the amplitude modulation 4~6kHz audio transmission capability, the FM band has 16kHz bandwidth in the message signal. And not just that, the FM radio station is need at least 10 times less power for the same coverage, than the AM broadcasting. After a few years this become the industries standard.

Now days, the frequency modulated radio broadcasting is between 87.5MHz and 108MHz all of the European ITU[2] countries. Because it is not a free band, like the ISM band which contains the wifis 2,4GHz, the users have to pay fee for usage of one 300 kHz raster window for their radio program. That is very expensive. In Hungary the National Media and Telecommunication Authority[3] (henceforth NMHH) supervises the frequency management. There are three classes for radio broadcasters over 1kW, under 1kW and under 10W, the last one is for small community radios, this is the most problematic type of radios. The ITU standard defines the maximum for the frequency deviation, which is 80 kHz and offers a modulator with 75kHz/V slope rate.

The licence price is very high, so the NMHH have to check the authorised and unauthorised users to fill the requirements. It's trivial that the unauthorised user must keep away this band and they have to shut down, but the authorised users also have requirements. Some of this parameters is: the maximum bandwidth is 300 kHz, the radio stations over 1kW is have placed in dedicated spots, the under 1kW radio station places have to checked before it gets work and in the small community radios area the people have to agree the radio. But, the most conflicts are starts with the frequency deviations measurement results, because the station owners and the NMHH never measure the same. And it is not an easy measurement.

II. Simulating Radio Signals in the Baseband

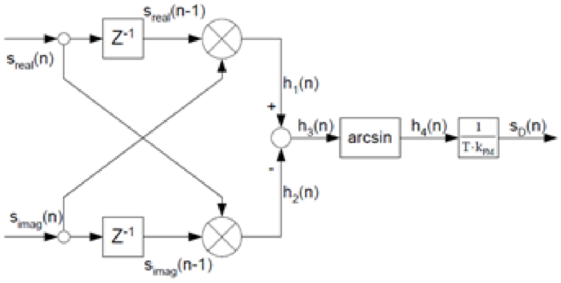
The modulations are based on the sinusoid carrier signal parameters modification *{2.1.}*. First is varying the amplitude of the carrier, this creates the AM (amplitude modulated) signal, the second is to varying phase (φ), this makes the PM (phase modulated) singnal and the last is to modifying the frequency and this is the FM signal.

$$f(t) = A_c * sin(2\pi f_c t + \varphi) \qquad \{2.1.\}$$

FM signal creation is not that easy, because the message signal integrated function used for the transmission *{2.2.}[1]*. With this extension the message reconstruction become more robust and very easy to keep out noise from the system.

$$f_{FM}(t) = A_c * cos\left(2\pi f_c t + k_{FM}\int_0^{\vartheta} f_m(\vartheta)d\vartheta\right) \{2.2.\}$$

We can make the complex envelope of the signal which described by *{2.2.}*, with frequency transpose and Hilbert



1. Figure: Real baseband delay FM demodulator (adapted from: *[5]*)

transformation *[2]*. After these transformations we got a signal, which running around the zero frequency, like it does with the carrier *{2.3.}*. This means we got a signal with a zero frequency carrier, but this signal not contains all parameters of the original if it has only real part, so it's become a complex function. We lose a lot with complex

[1] IEEE-USA Today Engineer (*http://www.todaysengineer.org/2008/Dec/history.asp*)
[2] International Telecommunication Union (*http://ITU.int*)
[3] NMHH (*http://www.nmhh.hu*)

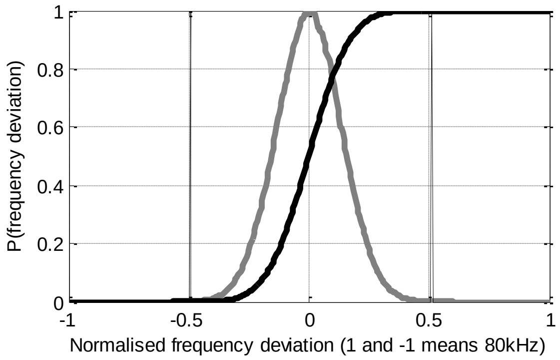
number representation, but this is at least hundred times smaller than what we win.*[3][4]*

$$\hat{f}_{FM}(t) = A_c * e^{jk_{FM}\int_0^{\vartheta} f_m(\vartheta)d\vartheta} \qquad \{2.3.\}$$

The calculations before creates the modulated signal, but it have to be demodulated the analyse the transmission line. To demodulate the FM signal near to twelve methods to do it. After some test runs I choose the real baseband delay structure, because it was the fastest *{1. Figure} [5], [8]*.

III. Define and measure the frequency deviation

In the laboratories environment with a measuring signal it is really easy to define the modulators maximum deviation. In the real life there is no measuring signal, there is only the music and speech which is the program of the radio, but this is not a problem. The speech and music signals are tending to a well-known noise in long time measurement sets - this means 60 seconds – the pink noise. With this constraint, radio is broadcasting pink noise, the deviation maximum is easily calculated *{2. Figure}*.



3. Figure Amplitude frequent function (own)

Stochastic message signals deviation calculations shows the *{3.1.}* calculation and results showes by *{2. Figure}*, the gray line is the amplitude frequent and the black line is the integrated of the dispersion function. The maximum value of the deviation is the point where the probability is reaches the 1/10000 of maximum – usually the zero – value *[6]*. The *{3.2.}* and *{3.3.}* calculations shows the definition of frequency deviation values *[9]*.

$$d_m(z) = \sum_{n=0}^{z} hist\big(fm(n)\big) \qquad \{3.1.\}$$

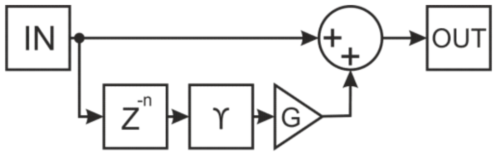
$$D_{max} = z, where\ d_m(z) <> \frac{max(d_m)}{10000} \qquad \{3.2.\}$$

$$D_{min} = z, where\ d_m^*(z) <> \frac{max(d_m)}{10000} \qquad \{3.3.\}$$

IV. Propagational channel model

There are lots of models in this area, two basic types the Rician and the Rayleigh, the difference of the two statistical models is that the first is a LOS (line of sight) and the second is a NLOS (non-line of sight) propagation descripting model. The easiest is the two way LOS topology, it contains a delay and attenuator *{3. Figure}*. Complex delay is important, because with it we can define phase shift to. This makes us the less than one sample delays *[7]*.

Description of the vector-normed space, which is descripted by the two-way Racian model, is *{4.1.}* and *{4.2.}*.



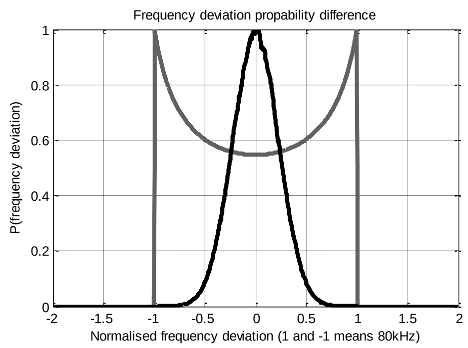
2. Figure 2-way propagational model (own)

$$f(t,d,a) = \frac{1}{a}\sum_{i=1}^{d} f(t-i) \qquad \{4.1.\}$$

$$f(t,d,a,\varphi) = \frac{1}{a}\sum_{i=1}^{d} f(t-i) * e^{-i\varphi} \qquad \{4.2.\}$$

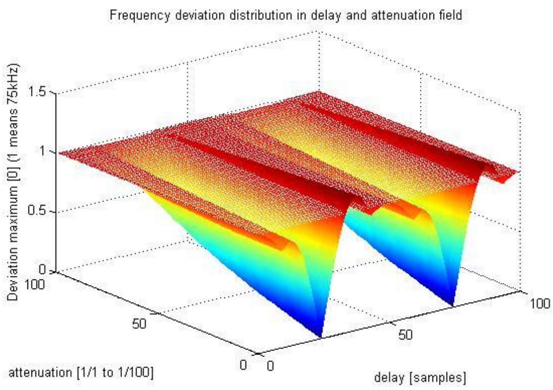
V. Results

The first result is that, there is very clear difference between the sinusoid message signals deviation its maximum is 1, which means it is the same as the maximum deviation and the pink noises maximum is 0.84 times smaller *{4. Figure}*.



4. Figure The difference between the sinusoid and the pink noise message signals deviation probability (own)

The second result is that, there is a real variation in the reflected signal and the original signal. The delay and the attenuation strains a field with three axis, one axes is the delay, the second is the attenuation and the third is the maximum of the deviation. *{5. Figure}* shows this surface.



4. Figure Frequency deviation trends (own)

CUNCLUSION

The results shows us that the problem is real and we have to calculate with it. The complex baseband description of the radio frequency signal is truly gives us a faster simulation and made problem feasible. Now we can say that the basic problems are solved.

Future option is to generalize the problem and make a formula for measurement corrections.

REFERENCES

[1]: E. H. Armstrong, "A Method of Reduscing Disturbances in Radio Signaling by a System of Frequency Modulation", Proceedings of the Institute of Radio Engineers, vol. 24, issue 5, pp. 689-740, 1936

[2]: E. Bedrosian, "The Analytic Signal Representation of Modulated Waveforms", Proceedings of the Institute of Radio Engineers vol. 50, issue 10, pp. 2071-2076, 1962

[3]: S. Hykin, Communication Systems, 4th ed., John Wiley & Sons, Inc., 2001

[4]: L. W. Couch, "Complex Envelope Representations for Modulated Signals", in The Mobile Communications Handbook, 1st ed., Suthan S. Suthersan, Boca Raton: CRC Press LLC, 1999

[5]: F. Schnyder, C. Haller, "Implementation of FM Demodulator Algorithms on a High Performance Digital Signal Processor", MSc Thesis, Hochschule für Technik Rapperswil and Nanyang Technological University, Germany and Singapure, 2002

[6]: ITU-R workgroup, "Method of Measuring the Maximum Frequency Deviation of FM Broadcast Emissions at Monitoring Stations", France, European Recommendations, ITU-R SM.1268-1, 1999

[7]: F. P. Fontán, P. M. Espiňeira, Modelling the wireless propagation channel: a simulation approach with MATLAB®, Singapore, John Wiley & Sons, Inc., 2008

[8]: J. M. Shima, "FM Demodulation Using a Digital Radio and Digital Signal Processing", MSc Thesis, University of Florida, USA, 1995

[9]: A. V. Oppenheim, R. W. Schafer, Discrete-Time Signal Processing, 3rd ed., Prentice Hall, 2009