A Fast Algorithm for Electromagnetic Compatibility Estimation
For Radio Communication Network in a Complex Electromagnetic Environment

Clement Temaneh-Nyah

Department of Electronics and Computer Engineering, University of Namibia
Ongwediva, Namibia

cntemaneh@unam.na, clementtemaneh@yahoo.com

Abstract— Electromagnetic compatibility (EMC) is the ability of a Radio communication Equipment (RCE) to operate with a desired quality of service in a given Electromagnetic Environment (EME) and not to create harmful interference with other RCE. This paper presents an algorithm which improves the simulation speed of estimating EMC of RCE in a complex EME, based on a stage by stage frequency-energy filtering criterion. This algorithm considers different interference types including: Blocking and intermodulation. It consist of the following steps: simplified energy criterion where filtration is based on comparing the free space interference level to the industrial noise; frequency criterion which checks whether the interfering emissions characteristic overlap with the receiver’s channels characteristic and lastly the detailed energy criterion where the real channel interference level is compared to the noise level. In each of these stages some interference cases are filtered out by the relevant criteria. This reduces the total number of dual and different combinations of RCE involved in the tedious detailed energy analysis and thus provides an improved simulation speed.

Keywords - Electromagnetic compatibility, Electromagnetic Environment, simulation of Communication Network.

I. INTRODUCTION

The sum of all electromagnetic fields at a given point in space is called the electromagnetic environment (EME) and is created by different sources of electromagnetic radiation including technical equipments and natural electromagnetic processes [1]. The ability for a radio communication equipment to perform its required task at a given point is completely determined by EME and the technical specifications of the equipment. Electromagnetic compatibility (EMC) is the ability of a Radio communication Equipment (RCE) to operate with a desired quality of service in a given Electromagnetic Environment (EME) and not to create harmful interference with other RCEs. The problem of EMC estimation is one of the main components in the frequency-terrestrial planning of radio communication systems. The EMC estimation answers the question whether a given RCE will function with the required quality of service in a given EME. Simulation of EMC of RCE by mathematical modeling has become increasingly prominent [2] due to the fact that experimental studies of EMC require too much time and can be financially expensive in nature. The different models used include: mathematical models of transmitter emission, the receiver susceptibility, antenna-feeder devices, propagation channel, different noise and random effects [3]. The computational efficiency and simulation accuracy are facing challenges particularly in areas with high concentration of RCE where the number of used frequencies $n$ may approach a high value $n \sim 10^{4}$. The number of dual combinations of RCE needed for analysis in this case is proportional to $n(n-1) \sim 10^{8}$, and for the two signal intermodulation combinations formed by triples of RCE - $n(n-1)(n-2)/2 \sim 10^{12}$. Therefore fast, accurate and comprehensive approaches for EMC estimation in such complex EME is required, and have become a research focus. There are therefore two major aspects of concern in EMC estimation, namely, the aspect of accuracy and that of simulation speed. The accuracy aspect depends on the adequacy of the models used, while the speed aspect depends on how the models are used. This paper looks at the speed aspect only. Therefore the paper presents an algorithm which improves the simulation speed of estimating EMC of RCE in a complex EME. The remainder of the paper is organised as follows: In section II, the two stage procedure of EMC estimation in the literature is presented. Section III is dedicated to the proposed stage by stage elimination procedure. Section IV, presents the EMC criterion which can be applied in the case of both blocking and intermodulation interference. Lastly, the conclusion is given in section V.

II. EMC ESTIMATION ALGORITHM

EMC estimation is performed by considering the whole interacting RCEs as a single, large physical system and therefore requiring a comprehensive approach, consisting of the following three stages: mathematical modeling of RCE, mathematical modeling of EME, analysis of the effect of EME on RCE while accounting for many different factors. The most important factors being: the properties of radio waves propagation in the
surface channel, multiple access, received signal level fluctuations and interference representing random processes. The input data for EMC estimation are: the characteristics of radio communication equipment which are used to construct the mathematical models of the receiver, transmitter and antenna feeder device.

EMC estimation by the above method is often divided into several stages (parts), in order of increasing computational complexity due to the large number of computation needed. The most common of the different stages [4, 5, 6], is shown in Fig. 1 and comprises of frequency and the energy criteria.

![Fig. 1 Different stages in EMC estimation](image)

III. PROPOSED ALGORITHM

The proposed algorithm is based on a stage by stage frequency-energy criteria filtration consisting of the following steps: simplified energy filtration criterion; frequency filtration criterion and lastly the detailed energy filtration criterion. In each of these stages, the relevant criterion filters out some interference cases hence resulting in a reduction in the total number of dual and different combinations of RCE needed to perform the tedious detailed energy analysis. This therefore will result in an improved simulation speed. The proposed algorithm considers Blocking and intermodulation interferences and consists of the following steps as shown in figure 3:

<table>
<thead>
<tr>
<th>Analysis Stage</th>
<th>Mathematical Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wanted and interference signal levels</td>
<td>Transmitter Model</td>
</tr>
<tr>
<td>Computation of propagation loss in the radio communication</td>
<td>Radio Communication Channel Model</td>
</tr>
<tr>
<td>Wanted, interference and noise signal levels at the receiver’s input</td>
<td>Antenna Model</td>
</tr>
<tr>
<td>Electromagnetic Compatibility Computation</td>
<td>Receiver Model</td>
</tr>
<tr>
<td>Models of Noise and Industrial interference</td>
<td></td>
</tr>
</tbody>
</table>

![Fig. 2 A typical energy criterion based EMC estimation scheme](image)

A. Simplified energy criterion

The interference level for each interference source (transmitter’s main, spurious or Out-of-Band emissions) at the victim receiver’s input is estimated using the simple free space propagation model. The result for each source is then compared to the industrial noise level at the victim receiver’s input. A particular interference source is eliminated from the detailed EMC estimation stage, if the interference level is less than the industrial noise level.

B. Frequency criterion

The characteristic of each interference source that was not filtered out in stage 1 above is compared with the characteristic of the appropriate receiver’s Main or Spurious channels. If these two characteristics do not overlap, then the given interference source is eliminated from the detailed EMC estimation stage.

C. Detailed energy criterion

The interference level from each of the interference sources that were not filtered out in stages 1 and 2 above is estimated using the real and tedious channel model. Each of this interference level is then compared to the victim receiver’s total noise level and eliminated when its level is less than the total noise level.

In each of these stages some interference source are filtered out by the relevant criteria and therefore do not take part in the detailed and tedious computation. This reduces the total number of dual and different combinations of RCE for the tedious detailed energy analysis thus providing an improved simulation speed. Based on the victim receiver’s model, the change in the victim receiver’s qualitative characteristic due to the impact of the interference is analysed. The next stage
computes the EMC based on the chosen EMC criteria. The decision of electromagnetic compatibility or incompatibility of RCE is adopted based on the EMC criterion defined by the inequality (1).

IV. CRITERION FOR EMC OF RCE

The EMC of RCE is satisfied when:

\[ P_C - P_N \geq A, \]  

(1)

where

- \( P_C \) - wanted signal power at the receiver input, dBmW;
- \( P_N \) - interference signal power at the receiver input, dBmW;
- \( A \) - Protection ratio for the given type of RCE and interference, dB.

This criterion does not apply in the case of both blocking and intermodulation interference because firstly, interference level is not informative and secondly in case of multiple interference. Therefore, the above equation (1) is modified as follows:

\[ P_C - P_{N_{\Sigma}} - \Delta h \geq A, \]  

(2)

where

- \( \Delta h \) - decrease in sensitivity due to the effect of interference on the receiver. It shows by how much the minimum wanted signal level (which equals the sensitivity of the receiver) should be increased for inequality (2) to be satisfied.

- \( P_{N_{\Sigma}} \) - the total power of internal and external noise at the receiver input;

\[ P_{N_{\Sigma}} = 10 \log \left( \frac{P_{\text{int}N}}{10} + \frac{P_{\text{nat}N}}{10} + \frac{P_{\text{ind}N}}{10} \right), \]  

(3)

where

- \( P_{\text{int}N} \) — internal (intrinsic) noise power at the receiver’s input, dBmW;
- \( P_{\text{nat}N} \) — natural noise power at the receiver’s input, dBmW;
- \( P_{\text{ind}N} \) — industrial noise power at the receiver’s input, dBmW;

The condition (2) can be used in case of interference from the transmitter’s main, out of band or spurious emissions in the receiver’s main or side channels. It can also be used in the case of intermodulation and blocking interference, as well as account for the impact of noise and industrial noise. Note that in the worst case, the wanted signal power at the receiver’s input is equal to the sensitivity of the receiver: \( P_c = P_s \). Thus, if the wanted signal level exceeds the total internal and external noise level by the protection ratios, then any excess of the interfering signal over the total noise \( P_{N_{\Sigma}} \) (3) will lead to electromagnetic incompatibility.

Figure 3 Stages for EMC estimation
V. CONCLUSION

An algorithm for estimating the electromagnetic compatibility of radio communication equipment has been proposed. It is observed that due to the step by step criterion based elimination of possible interference sources, the number of interference sources finally involved in the tedious energy criterion estimation which involve the real channel is reduced and therefore explains the increase in the simulation speed, which is of great interest especially in the present scenario of complex electromagnetic environment caused by the increase in the number of sources of electromagnetic radiations. To quantify the increase in simulation speed using this algorithm, real data of characteristics will be needed.

REFERENCES


