AVERAGE DISTANCE APPROACH FOR INTERFERENCE CALCULATION BETWEEN IMT-2000 TRANSMITTERS AND FIXED COMMUNICATION NETWORKS

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ABSTRACT

In order to evaluate the electromagnetic compatibility between the terrestrial segment of IMT-2000 and other services allocated in the same frequency band, it is necessary to assess the expected levels of co-channel interference that would affect the receivers, a task that may not be simple when there are many transmitter/receiver pairs to analyze. In this paper, a methodology to evaluate such interference levels using an average value of the distance between transmitters and receivers is proposed. This is simpler than the conventional methodologies and does not introduce significant deviations as some examples proved, but the evaluation complexity is significantly reduced.

INTRODUCTION

The deployment of IMT-2000 networks may create new and complex interfering environments. The frequency sharing conditions between the different segments of the emerging IMT-2000 networks and other systems must be such that one service does not cause interference to the other in excess of the limits recommended by ITU-R [1]. For example, some fixed radio services are allocated in the same frequency band that will be used by the terrestrial segment of IMT-2000, making necessary the assessment of the co-channel interference levels that would be present at the input of each potential victim receiver, to implement some coordination measures. The conventional interference analysis consists on the computation of interference for every transmitter/receiver pair as well as the evaluation of the effect of all transmitters taken altogether. However, this procedure requires long processing-time, especially when the number of transmitter/receiver pairs is high. In this paper, a simpler approach for this assessment is proposed. Here, the interference that would affect each victim receiver is characterized by an average value that represents the expected level of interference within the area these receivers are located. To achieve this, an average value of the distance that separates transmitters and receivers is used. When using average distance, a deviation from the results obtained with a conventional analysis is expected. However, it enables a reduction of processing-time. Therefore, the effectiveness of the average distance approach depends on the value of such deviation. We were able to estimate the deviation for some examples and found it to be acceptable.

AVERAGE DISTANCE APPROACH

The idea of computing interference by using an average distance between transmitters and receivers was first presented in [2]. There, an interference environment in which some victim receivers are uniformly distributed in a "ring-shaped" area defined by two concentric circumferences of radius R_m and R_k, respectively ($R_m > R_k$), was considered. The distance from an interfering transmitter located at the center of both circumferences to every victim receiver is not the same, and if the receivers moves randomly, such a distance also varies randomly and so does the interference level at the input of every receiver. To evaluate the interference caused by the transmitter to a victim receiver, it was proposed the use of the average value of the distance between them, which best characterizes all the variations of the distance and therefore of the interference level. Such an average value is given by:

$$\overline{R} = 2\left(R_m^3 - R_k^3\right)/3\left(R_m^2 - R_k^2\right) \tag{1}$$

Theoretically, this equation may be used combined with any propagation model to analyze interfering environments similar to the described above. For example, if (1) is inserted into the well-known free-space propagation equation, the average interference can be expressed as:

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$$\bar{I} = (3\lambda/8\pi)^2 P_t G_t G_r L^{-1}\left(\left(R_m^2 - R_k^2\right)/\left(R_m^3 - R_k^3\right)\right)^2 \tag{2}$$

where P_t is the transmitted power, G_t is the gain of the transmitting antenna, G_r is the gain of the receiving antenna, L is the loss factor (no related to the propagation), and λ is the wavelength given in meters. Equation (2) represents the expected value of interference at the input of a receiver located within the defined area, regardless its actual position.

However, this approach provides an interference value averaged along a circumference, while the receivers are actually distributed on a plane. If we place the interference environment in the polar coordinate system, the probability that a receiver is located in an area element is given by:

$$f(r,\theta) = \frac{1}{\pi\left(R_m^2 - R_k^2\right)} r\,dr\,d\theta \tag{3}$$

so, an interference value averaged over the whole area (let us denote by $\tilde{I}$ to avoid confusions with that computed in (2)) can be obtained as:

$$\tilde{I} = \int_{R_k}^{R_m}\int_{0}^{2\pi} \frac{I(r)}{\pi\left(R_m^2 - R_k^2\right)} r\,dr\,d\theta = \int_{R_k}^{R_m}\int_{0}^{2\pi} \frac{P_t G_t G_r}{L}\left(\frac{\lambda}{4\pi r}\right)^2 \frac{r}{\pi\left(R_m^2 - R_k^2\right)} dr\,d\theta \tag{4}$$

where $I(r)$ is the free-space propagation equation. The final expression for this value is:

$$\tilde{I} = \frac{1}{2}\left(\frac{\lambda}{2\pi}\right)^2 \frac{P_t G_t G_r}{\left(R_m^2 - R_k^2\right)L} \ln\left(\frac{R_m}{R_k}\right) \tag{5}$$

The latter approach provides also an expected value, however it does not have the “flexibility” of the average distance and, in some cases, it is not easy to apply.

Even though the average distance approach was originally developed to analyze environments where relative displacements between transmitters and receivers exist, it can also be applied to the analysis of environments in which transmitters and receivers are fixed. This avoids the computation of the interference for every receiver, reducing the whole procedure to the computation of only one value with a simple equation, as it is shown in the following example.

Example 1

Consider an interfering transmitter operating at 1800 MHz with P_t = 10 dBW and G_t = 10 dBi, located at the center of two circumferences with radio R_m and R_k that defines the area in which n receivers with G_r = 15 dBi are uniformly distributed. Assume that only path loss and free-space propagation conditions exist. a) Compute analytically the expected interference value at the input of any of the receivers for different values of R_k (10, 15, 20, 25 km) and R_m = 30 km; and, b) simulate such an environment for different values of n (50, 500, 5000, 50000) and obtain the average interference for every case. Compare with the results obtained in incise a).

Solution: a) Applying (2), average distance approach, the expected interference for the different values of R_k is obtained and plotted in Fig. 1. This is equivalent to integrate along the circumference of a radius given by (1). Applying (5), an interference value averaged over the ring-shaped area is obtained for the different values of R_k and plotted in Fig. 1 too. Notice that, in general, integration over the whole area provides a higher interference value than integration along a circumference, but as the ring-shaped area narrows, the difference between the two values gets smaller. In this example, the maximum value of that difference is 1.0 dBm and, for values of R_k > 15 km, that difference is practically negligible, less than 0.5 dBm. This means that (2) provides an appropriate and simpler description of the average interference in comparison to that given by (4) and (5).

b) A computer program that generates randomly different locations of the receivers uniformly distributed on the ring-shaped area was implemented. At the end of every execution of the program, an average interference value was computed. These values are also plotted in Fig. 1, in order to make easier the comparison with those obtained analytically. Note how the average interference values obtained by simulation approach those computed analytically as the ring-shaped area narrows. For R_k = 10 km and 50 locations, there exists a great dispersion of the experimental values obtained, however, the deviation from the analytical results is still acceptable, no more than 3.5 dB, as shown in Fig. 2.

It is also noticeable that the deviation from the analytical values becomes smaller as the number of simulated locations increases. This is clear since the sum of the interference at the input of every receiver divided by n tends to $\bar{I}$ as $n \to \infty$. However, even for small values of n, the deviation from the average distance approach and from the integration over the whole area remains below 2.0 dB and 1.0 dB, respectively, for values of R_k > 15 km.

This example proves that the average distance approach provides reliable characterization of the expected interference in interference scenarios with characteristics similar to those of the terrestrial radio networks.

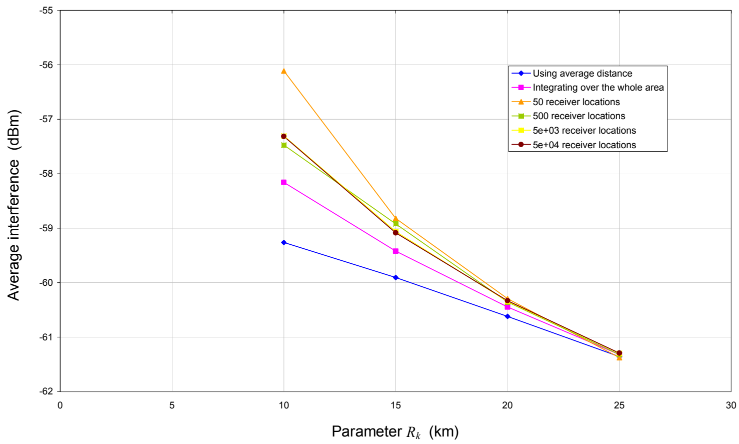
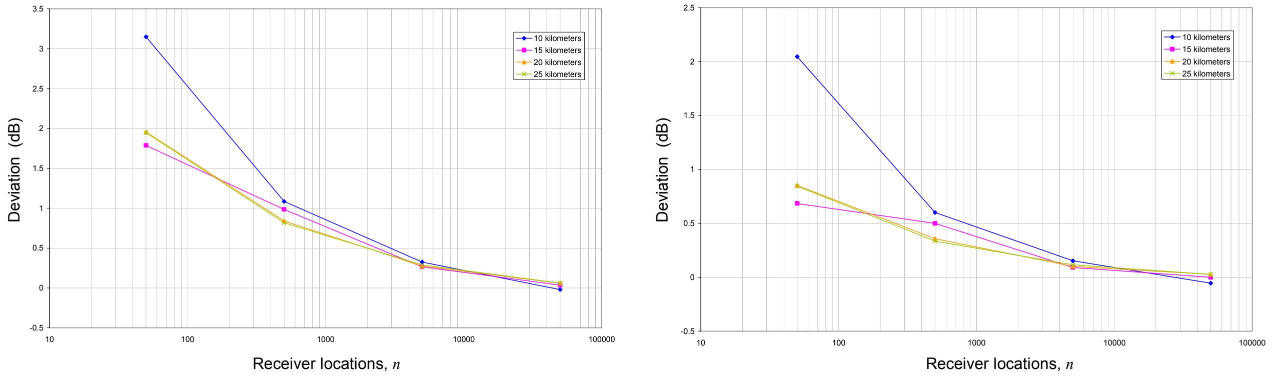


Fig. 1. Average interference values obtained analytically by applying average distance, by integrating over the whole area and by simulation.



(a)

(b)

Fig. 2. (a) Deviation of the average interference values obtained by simulation from those obtained by applying average distance and, (b) from those obtained by integrating over the whole area.

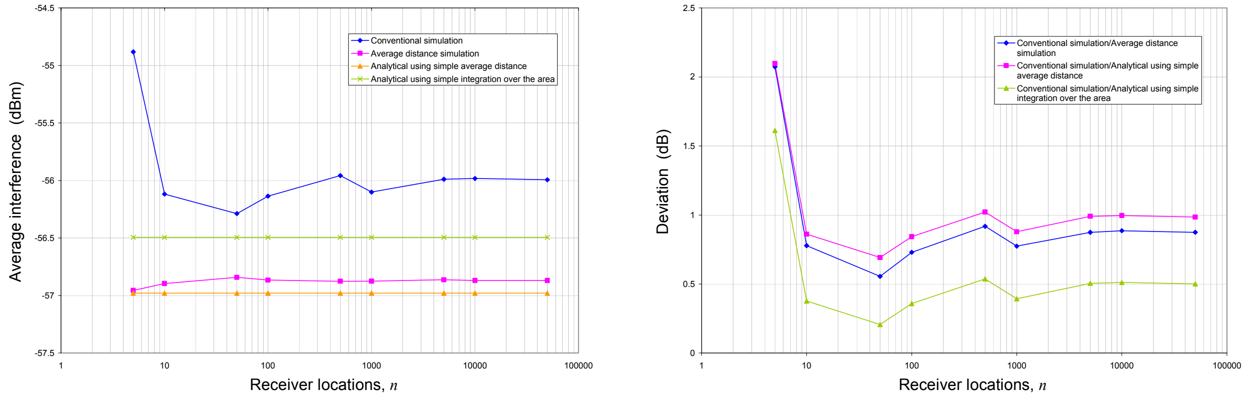
APPLICATION TO THE EMC ANALYSIS OF IMT-2000 ENVIRONMENTS

The deployment of new IMT-2000 networks may create complex interference environments, whether mobile or fixed, that can match the basic environment used for the development of the average distance approach. The average distance provides a way to evaluate interference analytically in combination with different propagation models. In some cases, the average distance approach may provide an alternative for assessing interference by simulation, reducing processing-time while maintaining the reliability of the estimations [3]. Let us consider an example to illustrate how the average distance concept can be applied to the EMC analysis of more realistic environments involving IMT-2000 networks.

Example 2

Consider an IMT-2000 system with CDMA access scheme allocated in the 2110-2160 MHz frequency band for downlink, to be deployed within a zone where fixed services (FS) microwave receivers are located and operating partially in the same band. Assume that the IMT-2000 system will operate with 10 MHz bandwidth carriers and that its 25 base stations are equally spaced a distance of 2 km, forming a square-shaped network. Use the same characteristics of the transmitters and receivers as well as the same propagation conditions of example 1, and for the FS microwave links consider a 50 MHz operation bandwidth and 8-PSK modulation scheme. The nearest and the furthest FS receivers are located at 20 km and 40 km from the center of the square-shaped network, respectively. If only the base stations that are assigned the upper frequencies of the band (consider 5), i.e., 2150-2160 MHz, affect the FS receivers, compute the expected interference value at the input of any of the receivers within the formed ring-shape area.

Solution: This environment is similar to the basic one used for the development of the average distance approach. The two simulation methodologies, conventional and based on average distance, described in [3], are the adequate options for EMC analysis in this case. The interference computed by applying these four methodologies is plotted in Fig. 3(a). The most accurate approach for predicting interference, in this case, is the conventional simulation methodology when it is executed with many iterations, i.e. $n > 10000$, however it is time-consuming. By using the concept of average distance, it is possible to simulate the scenario with less iterations, i.e. $n \sim 500$, with a deviation less than 2.5 dB in all the cases, as shown in Fig. 2(b). Despite the similarity with the environment of example 1, the transmitters are not concentrated in one central point in this example; therefore, (2) and (5) describe less accurately the received interference. However, by integrating over the whole area considering the interference sources concentrated in a central point, the minimum deviation is obtained, of the order of 0.5 dB.



(a) (b)

Fig. 3. (a) Average interference values obtained analytically and by simulation approaches and, (b) deviation from the conventional simulation results.

CONCLUSIONS

A simpler approach for the EMC analysis of the new interfering environments that may appear with the deployment of new cellular networks has been presented. This approach, based on the so-called average distance, simplifies the analytical estimation of the interference, as the examples showed. The approach has better performance when the area in which the victim receivers are distributed is narrow but, even for wide areas, the estimation is acceptable. When simulation is imposed to analyze more complex interfering environments, the average distance approach provide a way to reduce complexity, running-time and processing-time of the simulations, while maintaining an acceptable deviation from values computed with conventional techniques. The characterization of interference by an average value may be extended to the analysis of other fixed or mobile interfering environments.

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