AN INTERFERENCE ANALYSIS ON CELLULAR MOBILE RADIOCOMMUNICATIONS USING
CAD/CAE TECHNIQUES

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SUMMARY

The use of CAE techniques, as OMNISYS (EEsof) program, applied to the planning of cellular mobile radio systems is presented in this work.

The cochannel interference in a base-station's receiver of one cell produced by a mobile in another cell that uses the same frequency (frequency reuse planning) is studied. A OMNISYS simulation model of channel-plus-receiver is proposed, and used to carry out an interference analysis. Conclusions over the cell size and the cluster size of a cellular mobile radio systems are obtained.

1.- INTRODUCTION.

The recent increase of user's number in mobile communications services has carried out the development of more efficient techniques for planning this kind of systems.

Good quality service, cost effectiveness and efficient spectrum utilization are the fundamental aims of mobile communications systems design. Cellular radiocommunications attempt to provide the above goals. To achieve efficient spectrum utilization, frequency reuse is essential, and to design it both considerations have to take into account, the cell size and the cells number of the group with different frequency, that's the cluster size. The above system parameters depend of the environment where the cellular radio system is operating. There are different classifications of the environments¹, such as urban, suburban, rural areas, hilly rural areas, ...

For adequate planning of the mobile radio systems must be known the propagation model in the environment and frequency band of interest. In many publications^{2,3,4,5} have been presented different propagation models at all the frequency bands of interest for mobile radio systems. In those publications, the multipath phenomenon has been deeply studied and modelled in the interesting environments. Also, others propagation phenomenons, as the diffraction and absorption in buildings of urban environments⁶, have been studied. The statistical behaviour of the multipath phenomenon is modelled⁷ with very known probability density functions (PDF) as Rayleigh, lognormal, Rice, exponential. The Rayleigh PDF is used to model the multipath fading in environments where there isn't a predominant reflection signal (in a big building or hill), which is modelled

with the Rician PDF. These kinds of fadings are named fast-fading, due to the quick variation of the received signal level. The mean level of the received signal envelope, averaged over many Rayleigh cycles varies slowly, because of the objects in the path of the radio signal. This variation is named shadowing, and is modelled with a lognormal PDF, with a standard deviation between 5 and 9 dB, depending on the environment parameters.

In the study of mobile radio systems must be considered if the system is coverage limited or interference limited⁸. In an scenario where the transmitter powers are weak and/or any cochannel stations are widely separated, the radio system is limited by outage due to a failure to meet the coverage condition, that is, the received signal level is less than the threshold signal level (which is imposed by the receiver). This system is coverage limited. In other scenario where the transmitter powers are strong and cochannel stations are relatively close, the system is interference limited. Optimum transmitter power control has been studied⁹ to reduce the interferences in this kind of systems. In Cellular radio systems the most important interference is the cochannel interference against the adjacent cell interference¹⁰.

The quality of the service is measured by the Outage Probability parameter⁸, defined as a statistical measure that describes the probability of failing to achieve adequate reception of the signal at a particular location. To achieve adequate reception, the short-term desired signal must be simultaneously greater than both threshold signal level and the short-term sum of the interfering signal powers by the margin known as interference protection ratio. To asses quantitatively the concept adequate reception, several objective parameters of the signal and the receiver must be know, for relating it with the above margins. But, what are these objective parameters, since it depends of several characteristics of the signal, as modulation, for instance. Some studies have been carried out on this¹¹, but the conclusions aren't applied directly to modern mobile radio systems.

So that, to carry out a complete study of the above concepts will be very interesting to include the effect of both the channel as well as the receiver on the signal. For this, we have used a CAE tool as the simulator of RF/Microwaves systems OMNISYS (EEsof).

Figure 2. Block diagram of system channels-plus-receiver characterized.

In this paper some advantages of a powerful CAE technique to analyze interference problems in mobile radio systems are presented. Statistical model of the channel has been done in urban environment, adjusting the model parameters by comparison with models of other authors^{1,2,3,4,5} published previously for the same environment. We have modelled too, a common base-station receiver (TACS) of mobile radio operating in the frequency band 890-905 MHz. In particular, the cochannel interference on a base-station victim receiver produced by a mobile in a cochannel cell is studied, as is showed in the scenario of the figure 1.

Figure 1. Scheme of the scenario of the system analyzed.

II.- USING OMNISYS IN AN INTERFERENCE ANALYSIS ON CELLULAR MOBILE RADIO SYSTEM.

In the general structure to carry out a simulation of interferences (as first approximation we have considered just one interferer) must be take into account several elements as the wanted signal channel (mobile into the cell where is the victim base-station receiver), the interfering signal channel (mobile into another cell that uses the same frequency), and the victim receiver (base-station). The transmitter may not be considered if the same

kind of signals cross the two channels, and if the simulator have in library this kind of signal sources. The statistical characterization of the channels, with random delays (with a PDF) avoid the coherence between the wanted signal and interfering signal. Also independent sources for each channels may be used in OMNISYS version 3.5, not so in version 3.0.

The block diagram used in this work appears in figure 2.

In figure 2, it can be observed the hierarchical design capability of the program. We will analyze later the elements in particular. In the system block diagram there are several measure points (ports 2 to 6) to compare the degradation of the signal along the system. The input signal, depending on the analysis, is applied to the port number 1.

1) DESCRIPTION OF THE CHANNELS.

In this work we only have take into account the fading effect of the channel over the signal crossing it. Lognormal shadowing will be considered in a next work. The channels have been modelled using structures as appears in figure 3. Each of these structures is simulating a path signal (reflecting waves). The values of the Delays elements are obtained randomly following different statistics (exponential and Rayleigh). In other publications^{2,12,13}, results of delay profile measures in urban environment have been presented. As has been indicated^{12,13}, there isn't an specific model for the delay profile, although there's a trend to model it with exponential PDF. The value of the Pads elements model the loss due to distance-dependent path and absorption of electromagnetic energy by the objects where the reflections are produced.

Figure 4. Structure of the System Simulation with OMNISYS v.3.5.

Figure 3. Structure Delay-plus-Pad.

The wavenumber (signal paths) considered in each channels (wanted and interfering) is five, as is indicated^{12,13} in the experimental results obtained in urban environments. So, in this analysis we have considered the same environment (and so, the same fading) in both channels.

In other way, we can focus the model using the multiple source capability of OMNISYS v.3.5, and also the possibility to use the fading sources (Rayleigh, Lognormal, Exponential, Weibull,...) in library¹⁴. Then, the general structure of the simulation model is showed in figure 4.

In the structure of the figure 4, the input signal in each channel cross a substructure made with several (depending the wavenumber that is considered) branches as showed in figure 3, and after in each path signal is applied the fading, with the PDF that we have chosen. The difference with the previous model

proposed is that the statistical characteristic is not in the delays elements, but in the fading source. This last structure allows take account several combinations of the fading sources in the same channel, and different fading in both channels (different environment). This operating mode (multifading model) is used in several publications^{8,12,13,15}.

2) DESCRIPTION OF THE RECEIVER.

The capability of OMNISYS v.3.0 and v.3.5 to model, analyze and design general purpose receivers, and specific mobile radio receivers is demonstrated^{16,17}. In this work, a model of a base-station cellular radio receiver is presented, as is showed in figure 5. This receiver modelled correspond to a TACS base-station receiver in the band 890-905 MHz, and tuned to the frequency channel 898.485 MHz (25 KHz bandwidth).

OMNISYS have a extend components library to model any receiver, taking into account both linear and non-linear parameters in each components. The non-linear parameters may be defined in many way, since allows consider third-order intercept point, 1-dB compression point, power saturation, compression gain, intermodulation products tables in the mixers, internal noise, and so on. This characteristic have been considered in the model proposed, although because of the impossibility to know all this parameters in each component of the system, some

RECEIVER BLOCK DIAGRAM

Figure 5. Block Diagram of the receiver characterized.

of them have been intuitively adjusted, so that the global behaviour of the receiver obtained is a realistic approach.

Several analysis have been carried out in the receiver to adjust it, as "budget" analysis, frequency and power sweeps and modulated input signals.

In figures 6a, 6b and 6c, three measurements in the receiver are presented. In figure 6a, the result of a power sweep is showed. It may be observed the saturation characteristic of the receiver.

In figure 6b, the dynamic range (at 1-dB compression point) measurement is showed. In figure 6c, the Spurious Free Dynamic Range (SFDR) measurement is showed.

Figure 6a. Output power vs. Input power.

Figure 6b. Dynamic Range at 1-dB Compression.

Figure 6c. Spurious Free Dynamic Range.

III.- ANALYSIS IN THE GLOBAL SYSTEM MODELLED.

As has been indicated in the introduction, the quality of the service can be measured with the "Outage Probability", and to find it in our interference limited system suppose to determine the probability of achieving a certain threshold interference protection ratio (C/I) that produces bad reception.

For determining the C/I ratio in the frequency band 890-905 MHz, a frequency sweep analysis in this band has been carried out in the system block diagram showed in figure 2, with several values of distances d_w (distance from mobile wanted signal to base-station), and d_{int} (distance from mobile interfering signal to base-station). Figure 7 show one of this measurements of the C/I ratio (dB).

Figure 7. C/I measurement in the frequency band.

Due to the statistical behaviour of the channels (wanted and interfering), for planning mobile radio system will be interesting know the averaged value of the above measurement for different values of d_w (0.5, 1, 1.5, 2, 2.5 and 3 Km of cell radius) and d_{int} (8 to 13 Km with 0.5 Km of step). Some results are presented in figure 8.

In figure 8 can be observed as the averaged C/I ratio decrease (obviously) when d_w increase, for a constant value of d_{int} . However, also may be observed as for a constant value of d_w , the measurement C/I ratio (dB) not always increase when d_{int} increase, which is showed in the results, since the C/I curve for $d_{int} = 11.5 \text{ Km}$ is over the C/I curve for $d_{int} = 13 \text{ Km}$. With these results, and considering an scenario where d_w is the radius of the wanted signal cell, and d_{int} is the shortest distance between a location mobile in the interfering signal cell and the victim base-station, can be chosen an optimum pair of values (d_w, d_{int}), which will yield a maximum value of C/I ratio is obtained, and so, a minimum value of "Outage Probability", that is the aim of the cellular mobile radio systems design to obtain a good quality

service. So can be determined both the size of the cell and the size of the cluster.

Figure 8. C/I vs. d_w .

IV.- SUBSEQUENT STUDIES.

Several subsequent studies are being carried out on the line of this paper:

- It's being investigating what objective parameters of the signal used in this kind of mobile radio systems (depending on the modulation used: analog FM, QPSK, MSK, 0.3GMSK, p-QAM, $\frac{n}{4}$ -DPSK, ...), must be take into account to determine the relation between the C/I ratio and the qualitative concept "adequate reception". Will be interesting to know the limits of the above parameters for considering "adequate reception" in each particular case.
- Statistical analysis of the model channel-plus-receiver, using the statistical capability of OMNISYS to produce sensitivity histograms and performance histograms.
- Several combinations of the environments in the above proposed analysis.

V.- CONCLUSIONS.

In this paper an application of techniques CAE (OMNISYS RF/Microwave systems simulator) to study and planning cellular mobile radio systems has been presented.

Has been checked the capability of the program to determine the magnitude of interest (C/I ratio) in interference limited systems.

An OMNISYS simulation model of the channel-plus-receiver, that has allowed to carry out an

interference analysis in a cellular mobile radio system, has been presented.

In the analysis of the channel (wanted plus interfering) has been demonstrated that is possible to determine both the cell's size and the cluster's size of the cellular mobile radio system.

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