

Influence of DTX Function on the Base Station Power Decrease in GSM Systems

Aleksandar Lebl*, Vladimir Matic*, Mladen Mileusnic*, Dragan Mitic*, Žarko Markov*, Željka Tomić**

* IRITEL a.d., Belgrade, Serbia

** Tehnikum Taurunum VIŠSS, Belgrade, Serbia

lebl@iritel.com, vmatic@iritel.com, mladenmi@iritel.com, mita@iritel.com, zmarkov@iritel.com, zeljka@iritel.com

Paper dedicated to the fiftieth anniversary of Institute IRITEL

Abstract—In this paper the influence of discontinuous transmission (DTX) on the mean emission power of base station in GSM system is analyzed. Calculated results are obtained by implementing Erlang formulas for Markov modelled systems. These results are compared to the results obtained by simulation. Specific characteristics of signal transmission in GSM systems must be considered when influence of DTX on base station power is estimated. It is proved that considering only DTX without considering characteristics of signal transmission on different frequency carriers leads to underestimated values of base station power.

I. INTRODUCTION

Power saving is important demand in life, science and technology today. This goal is also obvious in modern mobile telecommunications. There are many ways how emission power of base stations is saved in mobile communications, i.e. many factors that influence base station power. Some of elements in this case are considering traffic load in base stations of mobile communication systems (power is not transmitted in idle traffic channels), structure of the traffic in the cell (relation of external traffic to the intra-cell traffic), adjusting emission power (power control) according to the distance between base station and mobile stations, users' distribution in the area of base station cell, implementation of lower rate codec (for example, half rate codec), and so on, [1]-[5]. Our aim was to analyze influence of discontinuous transmission function (DTX) on the base station output power.

II. DTX FUNCTION IN GSM SYSTEMS

During one conversation, there are periods when users are active (they are speaking) and when they are inactive (not speaking). It is usually supposed in literature that period of voice activity is $p_{DTX}=40-45\%$ of the conversation duration. The value $p_{DTX}=43\%$ is obtained as the solution of the Brady model, which is presented in [6], [7]. More precisely, we calculated the state probabilities for the model in Fig. 2 in [7], using matrix calculation. We obtained 4.8% the doubletalk probability, 18.6% the mute probability (both users are silent) and $p_{DTX}=43.1\%$ the probability that user A (user B) is speaking, alone or in a doubletalk phase.

The aim of DTX function in mobile systems is to stop mobile signal sending in case when there is no voice

activity. Signal switching off or on is based on the function of voice activity detection (VAD). When VAD finds that there is no voice activity, signal is not sent over traffic channels. In this way channel bandwidth is reduced (channel capacity is saved and signal from more traffic channels can be transmitted using available capacity). It seems, at a glance, that 55-60% of data bandwidth can be saved using DTX, and that, as the consequence, the same percent of base station emission power can be saved.

GSM systems are based on the implementation of time division multiplex (TDMA) and frequency division multiplex (FDMA). There are 8 TDMA channels on each frequency of FDMA (frequency carrier). The first frequency carrier is specific: it consists of signalling channels and traffic channels. The minimum number of signalling channels is 2 (when the number of frequency carriers is 1 or 2). In this case, there are 6 traffic channels on the first carrier. When the number of frequency carriers increases, the number of signalling channels also increases (usually, there are 3 signalling channels when there are 3 or 4 frequency carriers, as it is presented in [8]). In our analysis, we supposed, without significant influence on the accuracy of the results, that there are 2 signalling channels also when there are 3 or 4 frequency carriers. It means that we analyze systems with

$$N = 6 + (f_c - 1) \cdot 8, f_c = 1, 2, 3, 4 \quad (1)$$

channels, where f_c is the number of frequency carriers.

There is no power control on 8 channels of the first carrier – the emission power has its maximum value on these 8 channels. It means that the power on these 8 channels of the first carrier does not depend on the distance between base station and mobile station and that signal is always transmitted, independent of the VAD function. Traffic channels on the first carrier are seized first: channels on the following carriers (if available) are seized when all traffic channels on the first carrier are busy.

When we consider the presented characteristics of GSM systems, it is intuitively obvious that contribution of DTX to the base station power saving depends strongly on the offered traffic and on the number of available frequency carriers. It is also obvious that the percent of power saving when DTX is implemented compared to the situation when there is no DTX function is always less than

expected 55-60%. The aim in this paper was to determine the level of emission power saving in GSM systems as the function of the offered traffic.

III. METHODOLOGY OF ANALYSIS: CALCULATION AND SIMULATION

The analysis in this paper is based on the Markov models, which were developed for switching systems at first. Erlang formulas, as the solution for such systems, give the system important characteristics. Among these characteristics, the probabilities of the number of busy channels (state probabilities) are the most important for us. Starting from state probabilities, base station emission power can be very closely determined.

The probabilities of the number of busy channels can be expressed by the formula from some of the numerous references about queueing systems, i.e., more precisely, about Markov models and Erlang formulas, [9], [10]:

$$p(i) = \frac{\frac{A^i}{i!}}{\sum_{l=0}^N \frac{A^l}{l!}}, \quad i = 0, 1, \dots, N \quad (2)$$

As it is already explained, the emission power for all 6 traffic channels on the first carrier, whether they are busy or not, has its maximum value (P_{chmax}). On the other carriers there is no emission power when channels are idle and when there is no voice activity in the busy channel state. According to these considerations, base station emission power for traffic channels can be expressed as:

$$P = 6 \cdot P_{chmax} \quad (3)$$

when there is only one frequency carrier, and as:

$$P = P_{chmax} \cdot \left(6 + p_{DTX} \cdot \sum_{i=7}^{6+(f_c-1) \cdot 8} p(i) \right) \quad (4)$$

when there are $f_c=2, 3, 4, \dots$ frequency carriers.

More accurate value of emission power is obtained by simulation. The reason is the fact that Erlang formulas provide only the number of busy channels; it is not possible to distinguish with these formulas precisely which channels are busy and which are idle. Because of that, when we consider by calculation the situation when the number of busy channels is greater than 6, we suppose that 6 channels on the first carrier are always busy. But, in real traffic process, there are time intervals after the release of a channel on the first carrier when there are less than 6 busy traffic channels on this first carrier. As we emphasized, the power needed for traffic channels on the first carrier remains unchanged when some channel is released. When simulation is implemented for the analysis, it is possible to model precisely which channel is busy and which is idle. That's why we can have (on average) more busy traffic channels on frequency carriers with power control (second, third, fourth, etc. carrier) when simulation trial is performed, than when the results are calculated.

Simulation is based on *roulette* or *Monte Carlo* method, adjusted for telephone traffic calculations, [11]. This simulation program is upgraded to include value of

base station emission power and probability of voice activity in the connection, similar as it is presented in [1], [3], [5], [12], [13] for the analysis of different problems in mobile telecommunication systems. When simulation is performed, the state probabilities are determined on the base of traffic process simulation, and, at the end of simulation, base station power is calculated according to (3) or (4).

IV. POWER OF THE BASE STATION WITH DTX FUNCTION

In our analysis, we supposed that base station power in traffic channels is maximal, when signal is transmitted. It means that we haven't considered base station power control as the function of distance between the base station and the mobile station. Making such an approximation, we included DTX function as the single influencing component on the base station power.

Further, we suppose that the number of frequency carriers is not great (maximum 4). About 70% base stations have only 2 frequency carriers and 99% of them less than 7 frequency carriers, [14]. It is one more reason that we can adopt there are always 2 signalling channels on the first carrier.

Fig. 1-4 present mean value of base station emission power (P) as the function of the offered traffic (A), separately for the GSM system with one traffic carrier (6 traffic channels) in Fig. 1 to four frequency carriers (30 traffic channels) in Fig. 4. The values of P represent multiple of the maximum power needed for one traffic channel without DTX function. Two parallel characteristics are presented in each figure, the first one obtained by numerical calculation (curve "BS w/ DTX calculation") and the second one obtained by simulation (curve "BS w/ DTX simulation"). These characteristics are situated between two other characteristics, which are also presented. The upper one is determined for GSM system without DTX on active channels when there is emission power on all channels of the first carrier, regardless of their activity or inactivity (curve "BS w/o DTX"). The lower one is determined for the system with DTX implemented on all active channels, including also channels on the first carrier (curve "DTX"). The system modelled by this lower characteristic is usually supposed in the literature, when power saving caused by DTX is considered. Unfortunately, such analysis underestimates real mean and instantaneous base station power in traffic channels of GSM systems. The level of underestimation is as greater as offered traffic is smaller (for the situation when offered traffic is very small, for example during night, traffic analysis may be not necessary, because base station can go to the sleep mode, and the users from its area can be served by the neighbouring cells). The exception of the described characteristics' shape and position is the characteristic for one frequency carrier (Fig. 1), where three characteristics coincide: the characteristic for the system without DTX, simulation characteristic and calculation characteristic for the real system with DTX.

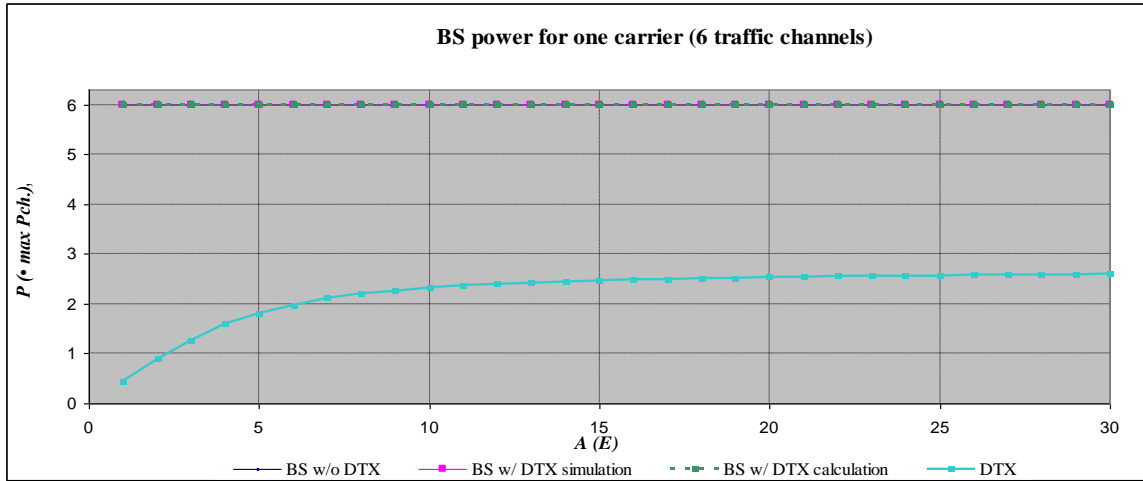


Figure 1. Base station emission power as the function of offered traffic when there is one frequency carrier (6 channels): the results of simulation (“BS w/ DTX simulation”) and calculation (“BS w/ DTX calculation”) compared to the system without DTX (“BS w/o DTX”) and to the system with DTX on all carriers (“DTX”)

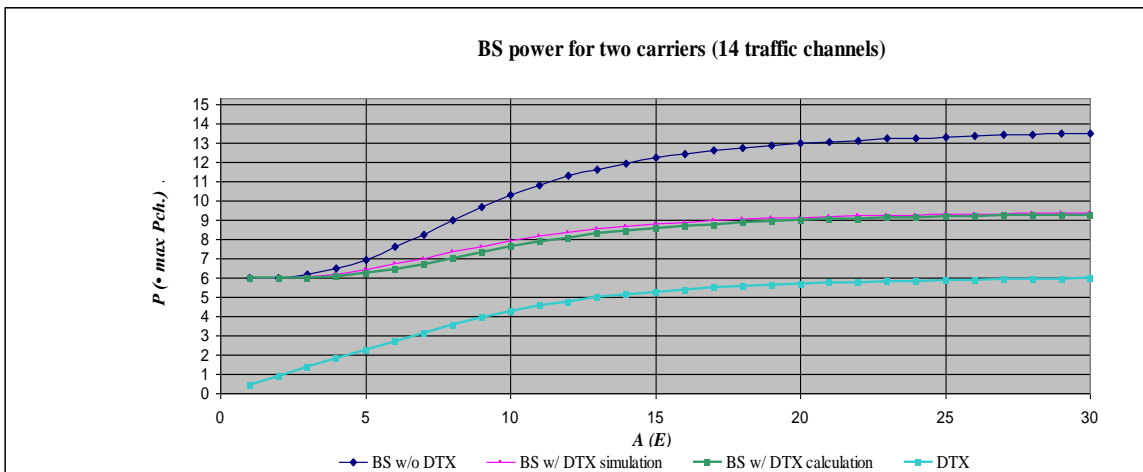


Figure 2. Base station emission power as the function of offered traffic when there are two frequency carriers (14 channels): the results of simulation (“BS w/ DTX simulation”) and calculation (“BS w/ DTX calculation”) compared to the system without DTX (“BS w/o DTX”) and to the system with DTX on all carriers (“DTX”)

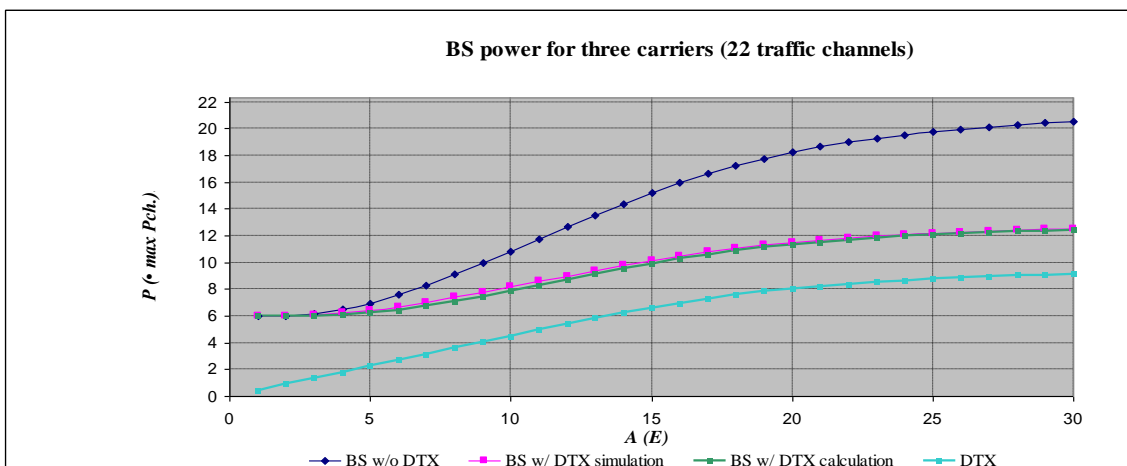


Figure 3. Base station emission power as the function of offered traffic when there are three frequency carriers (22 channels): the results of simulation (“BS w/ DTX simulation”) and calculation (“BS w/ DTX calculation”) compared to the system without DTX (“BS w/o DTX”) and to the system with DTX on all carriers (“DTX”)

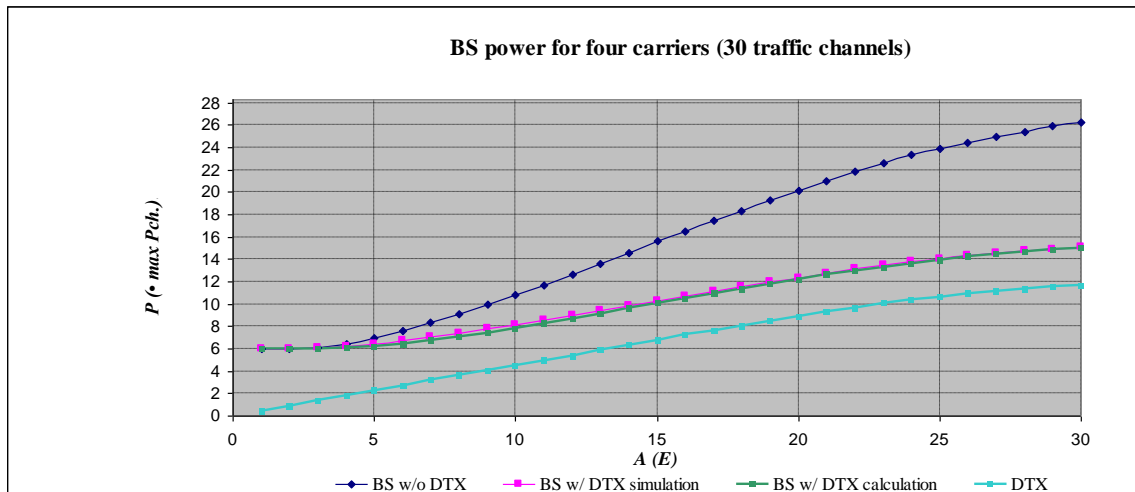


Figure 4. Base station emission power as the function of offered traffic when there are four frequency carriers (30 channels): the results of simulation (“BS w/ DTX simulation”) and calculation (“BS w/ DTX calculation”) compared to the system without DTX (“BS w/o DTX”) and to the system with DTX on all carriers (“DTX”)

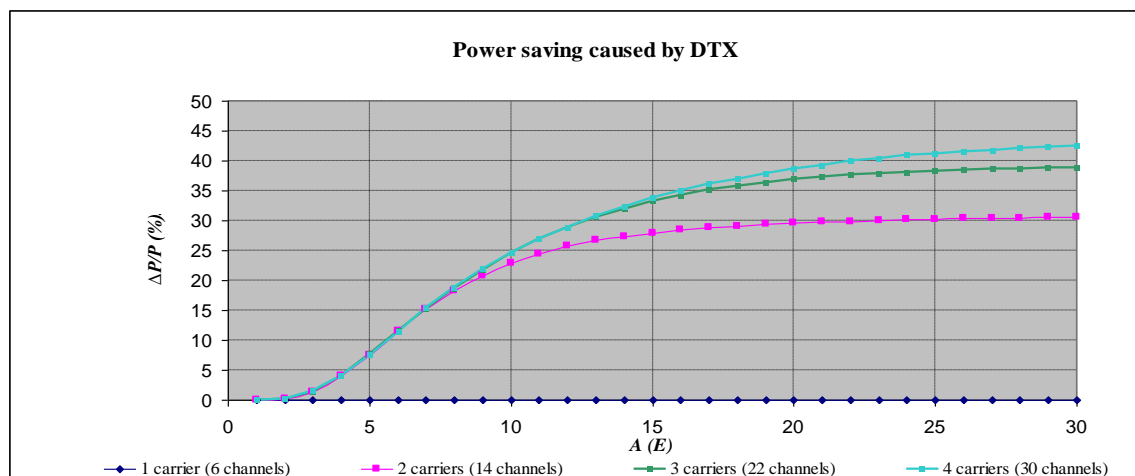


Figure 5. Relative decrease of base station power as the function of offered traffic for different number of frequency carriers

The calculated values of base station emission power in Fig. 1-4 are obtained using formulas (3) and (4), and, when calculation of state probabilities is considered, probabilities of the number of busy channels are obtained using formula (2).

It can be noticed, comparing the curves “BS w/ DTX calculation” and “BS w/ DTX simulation” that power values for the first of these two curves are never greater than the values for the second curve. The reason is, as already explained in Section III, the fact that Erlang formulas does not provide the data which channels are busy. If simulation is realized such that only the number of busy channels is considered, the results of simulation and calculation nearly match one to the other, but, unfortunately, these results are a little underestimated, comparing to the real situation.

Fig. 5 presents relative decrease of base station power as the function of the offered traffic when DTX function is implemented, comparing to the power in the systems without DTX. The curves for 1, 2, 3 and 4 frequency carriers are presented. Relative decrease is as greater as

the number of carriers is greater. As it is expected, there is no power decrease if there is only one frequency carrier.

V. CONCLUSION

In this paper it is presented how DTX function contributes to decrease of base station emission power in GSM systems. The power is not sent when traffic channels are in idle state and when there is no voice activity in busy traffic channels. But, traffic channels on the first frequency carrier are exception: signal is always sent in these channels regardless of the channel state (whether a channel is busy or not and whether there is voice activity or not in a busy channel). That’s why the effect of DTX function is smaller than it would be expected only on the base of its implementation in GSM systems.

Relative contribution of the DTX function to the base station emission power saving is as greater as the offered traffic is greater and the system is with more frequency carriers. When the offered traffic is small, or the system

consists of only one frequency carrier, DTX does not contribute to base station power decrease.

The results of this paper are important, when base stations are projected. These results are also important to perceive possibilities to reduce base station emission power, thus making contribution to power saving and, as the consequence, to environment protection.

ACKNOWLEDGMENT

The research presented in this paper is carried out within the project TR32051, financed by the Ministry of Education, Science and Technological Development of Republic of Serbia.

REFERENCES

- [1] M. Mileusnić, P. Jovanović, M. Popović, A. Lebl, D. Mitić, Ž. Markov, „Influence of Intra-cell Traffic on the Output Power of base Station in GSM“, *Radioengineering*, vol. 23, no. 2, June 2014, pp. 601-608.
- [2] P. Jovanović, M. Mileusnić, A. Lebl, D. Mitić, Ž. Markov, „Calculation of the Mean Output Power of Base Transceiver Station in GSM“, *Automatika*, vol. 55, no. 2, June 2014, pp. 182-187.
- [3] M. Mileusnić, M. Popović, A. Lebl, D. Mitić, Ž. Markov, „Influence of Users' Density on the Mean Base Station Output Power“, *Elektronika ir Elektrotehnika*, vol. 20, no. 9, November 2014, pp. 74-79.
- [4] D. Mitić, A. Lebl, Ž. Markov, „Influence of Traffic Model on the Calculation of BTS Output Power in GSM Network“, *AEÜ - International Journal of Electronics and Communications*, vol. 69, no. 5, May 2015, pp. 836-840.
- [5] A. Lebl, D. Mitić, M. Popović, Ž. Markov, M. Mileusnić, V. Matic, „Influence of mobile users' density distribution on the CDMA base station power“, *Journal of Electrical Engineering*, vol. 67, no. 6, December 2016, pp. 390-398.
- [6] P. T. Brady, „A Model for Generating On-Off Speech Patterns in Two-Way Conversation“, *Bell System Technical Journal*, 1969, pp. 2445-2472.
- [7] H-H. Choi, J-R. Lee, D-H. Cho, „Hybrid Power Saving Mechanism for VoIP Services with Silence Suppression in IEEE 802.16e Systems“, *IEEE Communications Letters*, vol. 11, no. 5, 2007, pp. 455-457.
- [8] E. M. M. Winands, J. Wieland, B. Sanders, „Dynamic Half-rate Connections in GSM“, *AEÜ - International Journal of Electronics and Communications*, vol. 60, no. 7, July 2006, 504-512.
- [9] L. Kleinrock, *Queueing Systems*, A Wiley-Interscience Publication John Wiley & Sons, 1975.
- [10] V. B. Iversen, *Teletraffic Engineering Handbook, ITU-D SG 2/16 & ITC, Draft 2001-06-20*, Technical University of Denmark, June 2001.
- [11] M. C. Jeruchim, P. Balaban, K. S. Shanmugan, *Simulation of Communication Systems: Modeling, Methodology and Techniques*, 2nd ed. Kluwer, Academic Publishers, 2002.
- [12] M. Mileusnić, T. Šuh, A. Lebl, D. Mitić, Ž. Markov, „Use of Computer Simulation in Estimation of GSM Base Station Output Power“, *Acta Polytechnica Hungarica*, vol. 11, no. 6, August 2014, pp. 129-142.
- [13] D. Mitić, A. Lebl, M. Mileusnić, B. Trenkić, Ž. Markov: „Traffic Simulation of GSM Cells with Half-Rate Connection Realization Possibility“, *Journal of Electrical Engineering*, vol. 67, no. 2, April 2016, pp. 95-102.
- [14] D. Colombi, B. Thors, T. Persson, N. Wirén, L-E. Larsson, M. Jonsson, C. Törmevik, „Downlink power distributions for 2G and 3G mobile communication networks“, *Radiation Protection Dosimetry*, vol.157, no. 4, 2013, pp. 477-487.