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others represent 1/2 and 1/3 of the main period. Another period of 175 h suggests a weekly cycle, but it falls below the reference and provides less confidence.

The global spectrum tends to smooth high frequencies, so the different peaks are not strictly comparable, and the cycles of 8 and 12 h probably are more important than they appear. The measurements also change with the exact site, which suggests looking for different patterns of variability in future studies, possibly at residential and business areas [5].

**Conclusion:** Given the variability found when measuring the 6' average EM field level prescribed by ENV-50166-2, this seems too a small window of measurement. Measurements made during 30' and 24 h have proved to be insufficient to ensure cyclic oscillations of power are identified. The series of ten days shows a clear daily periodicity, and signs of a slower one which requires longer measurements to be confirmed.

This work has shown that EM field strength in-urban areas has power oscillations around its mean level of extremely low frequencies, which suggests monitoring over intervals longer than 6' for more accurate characterisation. Future measures based on continuous monitoring, must look for longer power cycles and other properties hidden in data.

In short, highly populated urban areas are subjected to EM fields of power modulated at very low frequencies, the possible effects of which remain to be investigated.

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## Analytical method to compute capacity improvement of dynamic channel assignment with power control

Zhi Hua Zheng and W.H. Lam

An analytical method is proposed to compute the capacity improvement of a dynamic channel assignment with power control (DCA/PC). A closed-form expression is derived to calculate the capacity of the DCA/PC, which is improved more than 150% compared with fix channel assignment (FCA) and dynamic channel assignment (DCA) with no power control. The theoretical and simulation results show good agreement, the difference being less than 7%.

**Introduction:** Owing to the limited frequency spectrum, an efficient channel assignment scheme becomes an important issue in cellular network planning. Dynamic channel assignment with power control (DCA/PC) shows good performance and its capacity improvement evaluation based on simulations had been reported in the literature [1]. However, the related theoretical analysis is few due to the complex computation. In this Letter, an analytical method to compute the capacity improvement of DCA/PC is proposed. The analytical

results are compared with simulation results and good agreement is obtained.

**Capacity analysis of DCA/PC:** The capacity analysis of DCA/PC begins with the following assumptions. There are  $L$  orthogonal available channels divided into  $N$  groups,  $N$  being the cluster size. Each cell in the cluster has  $L/N$  available channels (nominal channels) allocated as fix channel assignment (FCA) [2]; however, when all nominal channels are busy in a particular cell other channels may be borrowed subject to ordered channel schemes [2]. The adjacent channel interference is neglected. When channels are released, reassignment may be initiated to ensure efficient utilisation. Furthermore, a distributed power control scheme [3] is also employed with the channel allocation to reduce the co-channel interference (CCI).

To predict the capacity of a cellular mobile system employed with DCA/PC, the Erlang-B formula is used to calculate the call blocking probability  $P_b$  with  $L/N$  channels in a cell under the FCA scheme, where  $P_b$  is given by

$$P_b = \frac{E^L}{(L/N)!} \left( \sum_{k=0}^{L/N} \frac{E^k}{k!} \right)^{-1} \quad (1)$$

and  $E$  is the traffic load in that cell in terms of Erlang,  $E = \lambda/\mu$ , where  $\lambda$  is the call arrival rate following Poisson process and the call hold time is exponentially distributed with mean  $1/\mu$ .  $E_B(L, P_b)$  is the offered traffic load in the cluster that yields a blocking probability of  $P_b$  with  $L$  channels, then the capacity  $C_{DCA/PC}$  in terms of Erlang density (Erlang per cell) for DCA/PC can be proposed as

$$C_{DCA/PC} = \frac{1}{N} E_B(L, P_b) \quad (2)$$

Consider that the signal strength  $S$  and total interference strength  $I$  received by a mobile terminal depend on both the user location within the cell and the co-channel users of other neighbour cells. Assume shadow fading is ignored, system capacity  $C$  can be expressed in terms of signal-to-interference ratio (SIR) and path loss as [1]

$$C = Ax2^{-SIR/1.5\alpha} \quad (3)$$

where  $A$  is a constant and  $\alpha$  is the path loss exponent. Denote  $SIR_{FCA}$  and  $SIR_{DCA/PC}$  as the FCA and DCA/PC scheme median value of SIR, respectively. Exercising the distributed power control in channel allocation, the DCA/PC scheme seeks to achieve maximum system capacity provided the SIR of each individual call is not less than system threshold  $\gamma$ . The resultant DCA/PC interference adaptation gain based on the FCA scheme is set to be  $\Delta G$ , where  $\Delta G = SIR_{FCA} - SIR_{DCA/PC}$ , and  $\Delta G$  is in units of dB. The interference adaptation gain coefficient  $g_{IA}$  of the DCA/PC scheme can then be deduced as

$$g_{IA} = \min(N, 2^{\Delta G/1.5\alpha}) \quad (4)$$

$N_p$  is the efficient cluster size of traffic adaptation and interference adaptation of DCA/PC, which can be proposed as

$$N_p = N/g_{IA} \quad (5)$$

Let  $P_j$  be the steady-state probability for  $j$  number of channels occupied in the cluster, which is given by

$$P_j = \frac{(N_p E)^j}{j!} \left( \sum_{k=0}^j \frac{(N_p E)^k}{k!} \right)^{-1}, \quad 0 < j \leq L \quad (6)$$

Obviously, when  $j=L$ , the arrival call will be blocked with the probability  $P_L$ . However, a new call may also be blocked even if the number of channels occupied in such cluster is less than  $L$ . Let  $b(m)$  be the probability that a channel cannot be assigned purely due to CCI [4], where  $m$  is the number of channels occupied in the cluster,  $b(m)$  can be written as

$$b(m) = \left( \frac{(1 - P_L)D}{(g + 1)L/N_p} \right)^{\lfloor (L-m)/N_p \rfloor}, \quad \text{where} \quad (7)$$

$$D = \frac{\lambda}{\mu} \left( 1 + \frac{g}{N_p} \right), \quad g = 2(N_p - 1)$$

The term  $[(1 - P_L)D]/[(g + 1)L/N_p]$  is the traffic carried by an individual channel per cell and the term  $[(L - m)/N_p]$  is the approximate average number of idle channels per cell in the cluster of size  $N_p$ .  $g$  is the number of co-channel interfering cells for a given cell and the operator  $[x]$  denotes the floor integer part of real number  $x$ . Thus, the traffic load  $E_m$  with  $m$  channels being occupied in the cluster is given by

$$E_m = N_p E(1 - b(m)) \quad (8)$$

The steady-state probability distribution of the DCA/PC scheme with  $j$  number of channels being occupied in the cluster is given by

$$P_j = \frac{\prod_{m=0}^{j-1} E_m}{j!} \left( 1 + \sum_{k=1}^L \frac{\prod_{m=0}^{k-1} E_m}{k!} \right)^{-1} \quad (9)$$

The call blocking probability  $P_b$  can be written as

$$P_b = \sum_{j=0}^L P_j b(j) \quad (10)$$

where  $b(j)$  and  $P_j$  are given by (7) and (9), respectively. Hence, the system capacity of DCA/PC can be calculated with (2) and (10).

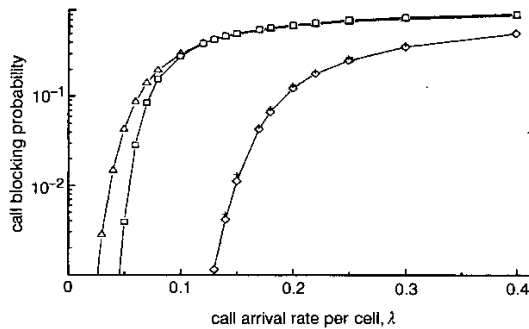


Fig. 1 Call blocking probability of FCA, DCA and DCA/PC schemes

-  $\Delta$  - FCA  
 -  $\square$  - DCA  
 -  $\diamond$  - DCA/PC  
 - - - simulation

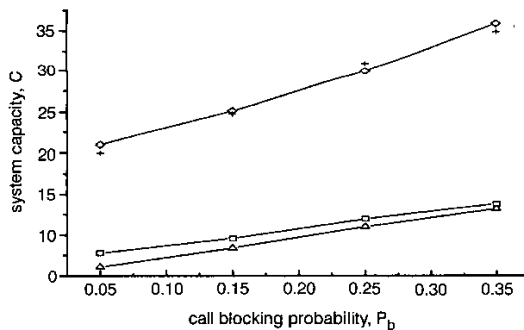


Fig. 2 Capacity comparison of FCA, DCA and DCA/PC schemes

-  $\Delta$  - FCA  
 -  $\square$  - DCA  
 -  $\diamond$  - DCA/PC  
 - - - simulation

**Numerical results:** To evaluate the capacity improvement of the DCA/PC scheme, assume that  $N = 7$ ,  $L = 70$ ,  $1/\mu = 120$  s, the resultant gain  $\Delta G$  is equal to 10 dB [1]. As shown in Fig. 1, when  $\lambda = 0.15$  the call blocking probabilities of the DCA/PC, FCA and DCA schemes are given by 0.011, 0.49 and 0.50, respectively. Observe that FCA is superior to DCA only when the traffic load is high; otherwise, DCA performs better. However, DCA/PC greatly reduces the call blocking probability  $P_b$  by more than 200% compared with that of DCA and FCA. The capacity comparison of the FCA, DCA and DCA/PC schemes is shown in Fig. 2. When  $P_b = 0.1$ , the capacities (Erlang/per cell) of FCA, DCA and DCA/PC are 7, 8

and 22, respectively. The capacity of DCA/PC is increased more than 150%. Moreover, the theoretical results resemble the simulation results as shown in Figs. 1 and 2. The difference is no more than 7%.

**Conclusion:** A closed-form expression of system capacity for the DCA/PC scheme is proposed. It is shown that the DCA/PC scheme has improved system capacity, more than 150%, compared with that of the FCA and DCA schemes. The analytical results are compared with simulation results and good agreement is obtained, the difference being less than 7%.

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## Blind estimation of carrier frequency offset for OFDM in unknown multipath channels

Y. Ma and Y. Huang

A novel method for the blind estimation of carrier frequency offset for orthogonal frequency division multiplexing (OFDM) is proposed. It is based on the second-order statistic algorithm. A special subcarrier weighting function is employed, which makes the estimation of the carrier frequency offset in an unknown multipath channel very efficient. Simulation results have demonstrated the effectiveness and robustness of the proposed algorithm.

**Introduction:** Orthogonal frequency division multiplexing (OFDM) has received considerable attention recently. It has been adopted or proposed for a number of applications, such as digital audio broadcasting, digital video broadcasting, and wireless local area networks. The main advantages of OFDM include the immunity to multipath-induced inter-symbol interference (ISI) and impulsive noise, as well as possible high data rate and spectrum efficiency. However, OFDM systems are much more sensitive to the carrier frequency offsets (CFO) than single carrier systems [1]. Various blind estimation algorithms of CFO for OFDM systems have therefore been proposed. They can basically be classified into two methods: maximum likelihood and second-order statistic for the cyclostationary signals [2-4]. These algorithms provide satisfactory results under the assumption that the multipath channel is known. In this Letter, we propose a novel blind-estimation algorithm of CFO for pulse-shaping OFDM systems in an unknown multipath channel. The method is particularly suitable for the downlink of OFDM-based wireless systems.

**Signal modelling:** The baseband equivalent of a pulse-shaping OFDM signal is given by [4] as

$$x[n] = \sum_{k=0}^{N-1} \sum_{l=-\infty}^{\infty} c_{k,l} w[k] g[n - lM] e^{j(2\pi/N)k(n-lM)} \quad (1)$$