Performance Enhancement of GSM Cellular Phone Network using Dynamic Frequency Hopping

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Received on:4/7/2007
Accepted on:6/3/2008

Abstract:-
A fundamental problem in current cellular system is how to increase spectral efficiency of cellular system and handle blocking in the call between the subscribers. The present research offers solution to the above problem. In this work software simulator that can be used in the environment of cellular system is designed and implemented. This designed system shows how to increase spectral efficiency and enhancement blocking probability in cellular system by using Dynamic Frequency Hopping techniques. In this paper received power(Pr) threshold is proposed as one method of Dynamic Frequency Hopping technique. In each frame, received power is measured on the six used frequencies and the current hopping pattern is changed if the measured received power does not achieve the required threshold on at least one of them. The results indicate increasing the spectral efficiency by using Dynamic Frequency Hopping technique, the result of spectral efficiency versus traffic load with Dynamic Frequency Hopping is equal to (6.5 b/s/Hz), compared with Frequency Hopping (5.2 b/s/Hz) and GSM (3.5 b/s/Hz). This leads to an improvement in performance of system and reduce the interference allowing the users to achieve higher data rate.

الخلاصة:
يقترح البحث الحالي طريقة لتصميم و محاكاة بيئة الاتصالات الخاوية باعتماد تقنيات ديناملكية القْفز في التردد وذلـك لتحسـين معدل نقل البيانات وتقليل التداخل . كما تم ُأقتَراح عتبةُ لقدره المستقبلة (Pr) كأحدى تقنيات ديناملكية القْفز في الترددُ . حيث يتم قياس القدرة المستقبلة لكل تردد في النموذج المرسلة ذات الستة ترددات ويتم تغيير اي تردد في النموذج اذا كانت القدرة المستقبلة لتـردد أقل من العتبةَ المحددةَ. لتقم اداء النظام تم مقارنة النتائج المستحصلة لحالتى القفز في التردد وGSM . اظهرت النتائج زيادة كفاءة الطيف باستخدام تقنية ديناملكية القفزفي التردد, حيث كان مساوية الى (6.5 b/s/Hz) مقارنة مع القفـز فـي التـردد (5.2 b/s/Hz) و مع GSM (3.5 b/s/Hz).

Key word :frequency hopping , Dynamic frequency hopping, cellular system

1. Introduction:

Ever increasing data traffic and limited capacity are major causes for congestion in current cellular systems. It is also expected that congestion will occur in peak usage hours even in the third generation systems. By congestion, we mean that in *some* cells, there will be no more capacity left. More specifically, in a congested cell, there will be no more available data channels for use by additional mobile hosts (MH's) in the cell. Note, however, that control channels for signaling (or paging) may still be accessible by all (MH's) in a congested cell [1]. **A** number of techniques have been used to combat impairments in rapidly varying radio channels and to obtain high spectral efficiencies in cellular systems. Some of those are channel coding and interleaving, adaptive modulation, transmitter/ receiver antenna diversity, spectrum spreading, and dynamic channel allocation (DCA) [2]. This work utilizes a multiplicity of techniques, with an innovation in the frequency-hopping domain. This paper presents the results of the GSM with frequency hopping, GSM without frequency hopping and DFH. Frequency hopping has been utilized in GSM for improving system capacity [3] [4]. GSM uses random or cyclical frequency hopping (FH). Random frequency hopping (RFH), in combination with channel coding and interleaving, provides the benefits of frequency diversity and interference averaging Capacity improvements obtained by RFH in GSM are in the range of 30%–100%. Recent theoretical and simulation studies indicate that significant

https://doi.org/10.30684/ etj.26.3.7
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performance improvements can be obtained by taking advantage of the combination of frequency hopping (DFH). The key concept of DFH is to adjust or build frequency hopping patterns based on interference measurements and calculations[2] [4], in order to avoid dominant interferers. Direct implementation of DFH (measurement-based DFH) requires rapid signal quality and path loss measurements, significant

2. Dynamic frequency hopping:

Dynamic frequency hopping is a combination of dynamic channel assignment (DCA), where a channel is one frequency in a frequency hop pattern, and traditional frequency hopping. In DFH, frequency hop patterns are continuously modified for every link in a cellular system. Modifications are driven by rapid measurements of the quality of frequencies used in a system by all mobiles and base stations, with the goal of tracking the dynamic behavior of the channel quality and of interference, and of avoiding

strong interferers. Frequency hop pattern modifications can also be based on the fixed wireless network calculating interference levels based on knowledge of path losses and channel occupancy, which we refer to as network-assisted resource management of the DFH-based system .The form of DFH that achieves the best performance is full replacement DFH, since it allows for changes of all frequencies in a pattern to frequencies of better quality, provided that they are available. This is the most complex form of DFH that, when relying on the measurement-based approach, requires substantial amounts of signaling overhead for communicating from a base station to its mobiles what frequency hop patterns need to be used in the ensuing time period. Reduced complexity schemes have been also proposed, which reduce measurement requirements and signaling overhead. For example, the system might restrict hopping pattern changes to changing only one hop at a time, or the system might predefine a set of hopping patterns and restrict changes to one of those hopping patterns [4] [5]. Three methods for DFH pattern modification are acknowledged:

1) full-replacement dynamic frequency hopping, which assumes changing all current frequencies of poor quality after each physical layer frame.
2) worst dwell DFH, where only one frequency (the lowest quality one) in a frequency-hop pattern is changed.
3) threshold(SIR)-based DFH, where a subset of currently used frequencies is changed [2].

and interference avoidance techniques called dynamic frequency hopping signaling overhead , and synchronization between base stations. However, network-assisted resource allocation simplifies DFH deployment significantly and thereby makes it feasible [4] .

In this paper DFH based Pr is proposed as one method of DFH and introduce as additional method to DFH techniques as shown below:

4) Proposed technique: DFH based Pr, this method has lower complexity from anther methods of DFH. In this method a subset of currently used frequencies is changed. With this method, the pattern change is done sparingly. In each frame, Pr is measured on the six used frequencies and the current hopping pattern is changed if the measured Pr does not achieve the required threshold on at least one of them. Only the frequencies in poor conditions are changed. Any frequency that meets the threshold can be used as a replacement, and there is thus no need to scan all possible frequencies.

3. Blocking Probability Calculation:

The blocking (outage) probability is defined as the probability that the signal-to-interference ratio (SIR) is less than a specified threshold [6],[7],[8],[9]. For the purposes of this paper, the outage probability is defined as the probability that a call is blocked , and is a measure of the Grade of Service (GOS) . also referred to as a lost call. the traffic intensity offered by each user is equal to the call request rate multiplied by the holding time. That is, each user generates a traffic intensity of A_u Erlangs given by[10]

$$\mathbf{A_u = \beta T} \qquad \text{…. (1)}$$

where T is the average duration of a call and β is the average number of call requests per unit time. For a system containing (U) users and an unspecified number of channels, the total offered traffic intensity A, is given as

$$\mathbf{A = UA_u} \qquad \text{… (2)}$$

Furthermore, in a (C) channel trunked system, if the traffic is equally distributed among the channels, then the traffic intensity per channel,

$$\mathbf{A_{ch} = UAu/C} \qquad \text{...(3)}$$

the offered traffic is not necessarily the traffic which is carried by the trunked system, only that which is offered to the trunked system. The carried traffic becomes limited due to the limited capacity (i.e. limited number of channels).The maximum possible carried traffic is the total number of channels(C) in Erlangs. Traffic can be assumed to be uniform for macro cells. However, road structures need to be considered for microcells, and traffic can be allowed only along the streets. The new call arrival process is modeled as an independent Poisson process with a certain mean arrival rate. The new call durations are independent exponential random variables with a certain mean. The Erlang B formula determines the probability that a call is blocked and is measured of the GOS for trunking system which provides no queuing for blocked calls [10],[11].

$$\textbf{P[blocked]}=\frac{\frac{A^C}{C!}}{\sum_{K=0}^{C}\frac{A^K}{K!}}=\textbf{GOS} \qquad \textbf{.... (4)}$$

4. The Propagation Model:

The propagation model we adopt takes into account multiple random effects due to unpredictable changes in the radio channel. The wide-area mean of the received power from a given user is adequately described by a deterministic dependence of the received power on the distance between transmitter and receiver [12]. The most basic model of radio wave propagation is so called free space radio wave propagation. In this model, radio waves emanate from a point source of radio energy, traveling in all directions in a straight line, filling the entire spherical volume of space with radio energy that varies in strength with a 1/ d^2 rules, where d is the distance from the radio source. However, real world radio propagation rarely follows this simple model. In order to take these effects into consideration following propagation model is used in this research [13]:

$$\text{Pr} = \text{Pt}\ \frac{G}{PL} X_{\sigma} \qquad \textbf{.... (5)}$$

where Pr: Received power
Pt: Transmit power
G: Combined antenna gain of the transmitter and the receiver.
Xσ: Log-normally distributed random variable with 0 (dB) mean,and σ (dB) standard deviation
PL: Average path loss
Average path loss, PL, can be defined as follows[13]:

$$PL=\left(\frac{4\pi.d_O\ f}{v}\right)^2\left(\frac{d}{do}\right)^n \qquad \textbf{.... (6)}$$

where
do: Close–in reference distance
f: Carrier frequency
v: Speed of light
d:Distance between the transmitter and the receiver antennas
n: Propagation exponent [13].

The performance of wireless communication systems depends significantly on the mobile radio channel. Propagation models predict the average signal strength and its variability at a given distance from the transmitter. Different propagation models exist for outdoor and indoor propagation and for different types of environments (e.g., urban and rural)[14]

5.Spectral Efficiency:

The radio spectrum available for wireless data services and systems is extremely scarce, while demand for this service is growing at a rapid pace. Spectral efficiency(SE) is therefore of primary concern in the design of future wireless data communications systems. This efficiency is partly achieved by cellular systems which exploit the power falloff with distance of signal propagation to reuse the same frequency channel at spatially separated locations. However, while frequency-reuse provides more efficient use of the limited available spectrum, it also introduces unavoidable cochannel interference , which ultimately determines the bit error rates (BER's) available to each user. Thus, there is a tradeoff between the *system* spectral efficiency, measured in [b/s]/[Hz m] or Erlangs/[Hz m], and the communication link quality, measured in terms of the BER provided to the users .Another technique to increase spectral efficiency is to use multilevel modulation, such as M-QAM, which increase *link* spectral efficiency, measured in [b/s]/Hz, by sending multiple bits per symbol [15]. Capacity is related to the spectral efficiency of a system, as well as the amount of traffic offered by each user. The spectral efficiency (SE), measured in channels/km2/MHz,is expressed as[16]

$$SE = \frac{B_t\ /\ B_{ch}}{B_t N_c A_c} \qquad \textbf{....(7)}$$

$$SE = \frac{1}{B_{ch} N_c A_c} \quad \text{....(8)}$$

where B_t is the total bandwidth of the system available for voice channels (transmit or receive), in MHz, Bch is the bandwidth per voice channel in MHz, N_c is the number of cells per cluster, and A_c is the area per cell in square kilometers. The actual number of users that can be supported can be calculated based on the offered Load A_l by each user and the number of channels per cell [17].

$$SE = \frac{N_c \times B_t}{A_l} \quad \text{....(9)}$$

6. Simulation and Computer Model:

For designing model Matlab program was used to solve mathematical equations. After the variables are input to simulation program to complete environment of cellular design, the present model calculates the number of cells in cluster and the number of channels in cell and number of users in system as proportional to area and desire environment design. The aim of this work is to design and implement software systems that increase spectral efficiency, by design optimum environment and using (DFH) technique, besides handling and controlling all the operations performance in a cellular network with high quality agreement with mobile system criteria. Figure (1) below shows Simulation flowcharts for (DFH)[18].

14. Defined the required input:

This section, define the required input of proposed cellular system using several data, considered basic to select cellular system and design;-

U: The number of users in system (1300).
T: Average calling time(2 minute).
B : Average number of call requests per unit time(30/h)
f_o: Center frequency(900MHz).
hm:- The height of mobile antenna(2 m).
A_t : The desired area region design(urban - 33.669Km).
Gt : The transmitter antenna gain(4db).
Gr :The receiver antenna gain(4db).
Do: Close–in reference distance(50 m)
d : The distance between the transmitter and the receiver
Xσ: Log-normally distributed random variable with 0 (dB) mean ,and 8(dB) standard deviation
n: Propagation exponent(3.5)
Simulation type: Down Lnk
B_{ch}: channel bandwidth(50KHz).
B_t :total bandwidth(50MHz).

8.Calculate the Number of Cell in Cluster(K)

Specified radius of cell from program depends on region type, the area of one cell is determined to find the number of cells in cluster as follows

$$K = \frac{total\ .Area}{Area\ .of\ .one\ .cell} \quad \text{(10)}$$

The desired area is not uniform most of the time, the handling of this case it cell distribution on large area in region desire, to find connection points between the cell edges for purpose expand and best selection cell positions. The program calculate the cells number does compares results with standard values. If the calculated value is not correspond to standard values, the program calculates new value of cells number after radius is increased and comparison is repeated . The process of calculation and comparison is repeated to reach optimum value of (K).

9. Calculate the Transmitted Power

Depending on equation. (11) the program calculates the transmitted power [10]

$$\text{(11)} \quad pt = \frac{\Pr (4\pi .d)^2}{GtGr \quad (\lambda)^2}$$

The received power in equation is criterion value which makes handoff threshold at borders cell reached to optimum value. This ensures handoff threshold besides best radio coverage for all cell regions.

10. Calculate Height Transmitter Antenna

Calculation depends on received power at weak point received in cell and received power at borders cell and height antenna of mobile unit , and transmitter power is calculated in section (9), it is possible to calculate transmitted height antenna in expression[10]

$$\text{(12)} \quad ht = \sqrt{\frac{pr\ .d^{\ 4}}{ptGtGr \quad (hm)^2}}$$

11. Calculate the Number of Channels for One Cell (c)

The number of channels per cell depends on mobile telephone switching office (MTSO) and processing management frequency (channels).The program of distributing the channels number to equal cells number is the first step, but in peak hour's state it depends on complex style for cells distribution The number of channel per cell is a function of the total number of channel available, amount of available spectrum divided by channel bandwidth and the required carrier to interference ratio. The formula for this factor is [16]

$$C = \left(\frac{B_t}{B_{ch}} \right) / K \qquad \textbf{(13)}$$

12. Simulation Results:

The calculated value of received power is compared with threshold value. If the calculated value of (Pr) is greater than the threshold value of (-117dB), then the program takes next value from matrix for comparison with criterion value, to be near ending of the matrix. But when (Pr) is less than the threshold the program blocks the frequency which generates (Pr), hence new frequency is selected and the (Pr) is compared with threshold. If calculated value is greater than threshold then go to next array, but if the (Pr) is less than threshold going to blocking the frequency, select the new frequency to ending. For systems using any kind of dynamic frequency hopping (DFH), On the other hand, outage probability is given as follows; (Ms) receives its signal over (96) time slots. Each six time slots make a frame, so an Ms is monitored over 16 (96/6) time frames. The analyzed parameter, outage probability, is the ratio of the number of the frames the (Ms) is in outage over the whole number of frames (which is 16). The mobile station (Ms) is considered to experience outage in certain frame if in all the six time slots of that frame its (Pr) is less than the threshold value of (-117dB). Hence outage probability takes values between (0%) and (2%), which is the result of the robustness of frequency hopping systems against interference. Figure (2) illustrates the sequence of frame and time slots. It is enough for a frame to have at least one time slot with Pr above the threshold. A further performance criterion is simulated for systems which utilize variations of FH. Ratio of weak frequency hops over the whole (FH) pattern of a user Figure (3). If a hop has a (Pr) less than (-117dB), it is considered to be weak frequency hops.

12.1 Call Blocking Probability:

The performance of call blocking probability for implemented cellular network has been calculated using Erlang-B formula [equation (4)]. It is drawn versus the traffic (A) as shown in Figure (4). This figure presents a comparison of blocking probabilities in GSM systems (without FH), (with FH) and (with DFH). It is seen from this graph the blocking probability of FH at(load = 1) is equal to (0.002), is less than GSM-no FH at(load = 1) is equal to (0.0061). The blocking probability is suppressed considerably by applying (DFH). If we compare the Frequency Hopping systems for a loading of (3), GSM (no- FH) has a blocking probability of (0.18), where this probability for FH is less than GSM is to (0.01) for FH and (0.0) for DFH. As loading increases, blocking probability for GSM (no-FH) increases very fast, while for FH this increase is considerably slow. For DFH the blocking probability is (0) until loading (4), whereas after exploiting DFH, no single user experiences outage until a loading value of(4). It is seen from the graph In Figure (5) the blocking probability of FH at user = (60) is equal (0.011), is less than GSM (no FH) at user = (60)and is equal (0.021). The blocking probability is very low in DFH. If we compare between the systems for a loading of (60) at (70), GSM (no-FH) has an outage probability of (0.083), where this probability decreases to (0.016) for FH and (0.0) for DFH. As loading increases, blocking probability for GSM increases very fast, while for FH this increase is considerably slow. For DFH the blocking probability is (0) until users number (70), for DFH from (0) to (80). While improving the performance of a particular user , this assigned low-interference channel might have a severe interference impact on another user though , in which case it would not be assigned to that second user. For low users , both FH and DFH perform very well .

12.2Spectral Efficiency:

From results shown in Figure (6) it may be derived that traffic control could potentially increase the spectral efficiency by decreasing the traffic itself, since the reduced interference could allow the users to a achieve higher rate. Figure (6) shows the performances of these systems GSM without FH (no FH), with FH, with DFH. The performance of the DFH system which is proposed as a practical system and upper-limited by the DFH system is almost the same as that of DFH system. Another striking result of Figure (6) is the improvement in the average user spectral efficiency and hence in the high data rate coverage. Although for low loading the difference in spectral efficiency is not much for load = 1, GSM-no FH (3.5 b/s/Hz), with FH (5.2 b/s/Hz), with DFH (6.5 b/s/Hz), and the results show that with the help of the relays better with heavy traffic for load = (2.15), GSM (no FH) (2.3 b/s/Hz), FH (2.8 b/s/Hz), DFH (3.2 b/s/Hz). At loading = 4, the spectral efficiency for DFH is higher than that of GSM no- FH (1.1), FH (1.3**) .** Figure (7) shows the performance of Spectral efficiency with reuse distance (radius (m)). The Spectral efficiency is shown to be generally increased by decreasing the reuse distance. From optimal value of spectral efficiency the optimal value of reuse distance can be obtained, and from the optimal reuse distance also the minimum value of interference can be obtained. From results shown in Figure (8) it is seen the spectral efficiency increases, when the number of cell per cluster is decreasing. The optimal value (best the minimum) of the number of cell in cluster causes reduced interference, since the reduced interference could allow the users to achieve higher rates.

12. 3. Received Power:

A. Received Power with Distance in GSM (withoutFH):

Figure (9) shows the relation received power with distance in GSM for transmitter power (8 watt) we seen the received power is good at distance (0 to 200m). After (200m) the received power decreases without call falling even at (730m) the call falls under threshold received power (-117 dB). The signal is decreased after (200m) duo to the log normal noise effect and losses of environment. At (900m) and (1000m) the call falls, the received power is (-118dB) because effect of noise. In GSM (no FH) the one carrier frequency carries information signal, any effect noise on the signal causes drop in level of signal under threshold. In transmitter power (5 watt) we seen the received power is good at distance (0 to 200m). After (200m) the received power is decreasing without call falling even at (670m) the call falls under threshold received power (-117 dB). The signal is decreased after (200m) due to the log normal noise effect. At (750m) and (920m) the call falls, the received power is (-118dB) because of effect noise.

B. Received Power with Distance (with FH):

The results shown in Figure (10) are obtained in the same environment of GSM without frequency hopping. In Figure (10) the transmitted power is (8 watts) the received signal power is good (0 to 240m). After (240m) the level signal drops because of noise effect and losses of environment. At distance (930m) the buzzing on call under threshold value is (-117 dB), the signal power records (-118dB). In (970m) buzzing happens on call under threshold. In (5 watt) the signal power is good (0 to 130m). After (130m) the level signal drops because of noise effect and losses of environment. At distance (630m) the buzzing on call under threshold value is (-117 dB), the signal power records (-118dB). At (900m) and (980m) buzzing happens on call under threshold. The average drop call is decreasing because the information signals distribution is on six slots. When the noise has an effect on any slot the information is transmitted through another slot in chip.

C. Received Power with Distance (with DFH):

Figure (11) shows improvement in received power, we observe the received power does no exceed threshold level; it causes modification to any poor frequency by using new frequency at the same band before the call drops under threshold. In (8 watt) the received power is good (0 to 300m), after (300m) the power drops under (-5dB), it causes noise effect and losses. We see after (300m) the received power drops to (-20dB) at (350m), at (360m) the power becomes (-45dB), remaining in swing case. In (5watt) Pr is good (0 to 200m), after (200m) the signal is down – up without exceeding threshold (-117dB), even reaching (-117 dB) at (950m), causes path losses and noise effect occur.

12. 4. Ratio of Weak Frequency

A. Ratio of Weak Frequency (GSM)

Figure (12) shows the continuous call in the same place; at the graph we observe dropping of the call at 7 times. The user is stopping at the same place (without moving). The call continues at the same environment about (20 times) and the number of fall of the call is observed. In GSM the information signal is carried over one carrier frequency, the first case is more exposed to noise effect and path losses, multi path. We see after first repeater appears first call falls, the value of Pr is (-118 dB), second call in sixth repeater the value is (-131dB), in tenth repeater the third call drop in value is (-150dB) and with eleventh repeaters the fourth call drop in value is (-125dB), other call drops in thirteen repeater the fifth fall in value is (-167dB) and fifteenth repeater the sixth call drops in value is (-139 dB) and eighteenth repeater the seventh call falls in value to (-120 dB).

B. Ratio of Weak Frequency Hops (with FH)

Figure (13) below illustrates the effect of using frequency hopping, chip (six slots) at the same environment. The user is stopping at same place (without change place or position), the chip is changed about (20m) times, and we see the one call is dropped after sixth repeater. The value of (Pr) call is dropped to (-131dB), the frequency hopping technique avoids multi path or any other effects ,because the information signal distribution is on sixth slot.

C. Ratio of Weak Frequency Hops (with DFH)

In Figure(14) below it is clearly seen there is no drop in call due to using the (DFH) which increases the spectral efficiency and improves the blocking probability. The automatic modification replaces any weak frequency without drop in call, the distance between user and base station is about (300m) in design. The improvement is made clear by using (DFH). .

13.Conclusion

The proposed system has the ability to maintain the received signal power through communication processes and enhancement the blocking probability. This paper provides a new method that does not allow received signal power to drop. The performance of system is improved by using DFH. The results show increase in the spectral efficiency and enhancement system performance of blocking probability. The result of SE with DFH is (6.5 b/s/Hz), compared with FH (5.2 b/s/Hz) and GSM (3.5 b/s/Hz). It leads to an improvement in performance of system and reduces interference could allowing the users to achieve higher rate. Blocking probability is improved because of handling speed drop in received signal level for call. In systems of GSM, blocking probability increases very fast by increasing the number of users. In FH technique, the blocking increases slowly at the beginning. In DFH blocking probability increases very slowly with increasing the number of users. The received power method gives better performance than other methods of DFH. Because the speed of DFH/Pr process is faster than that of the other method by factor T/6 (where T is the processing time) .also The program is tracking received signal level for determining the handover process.

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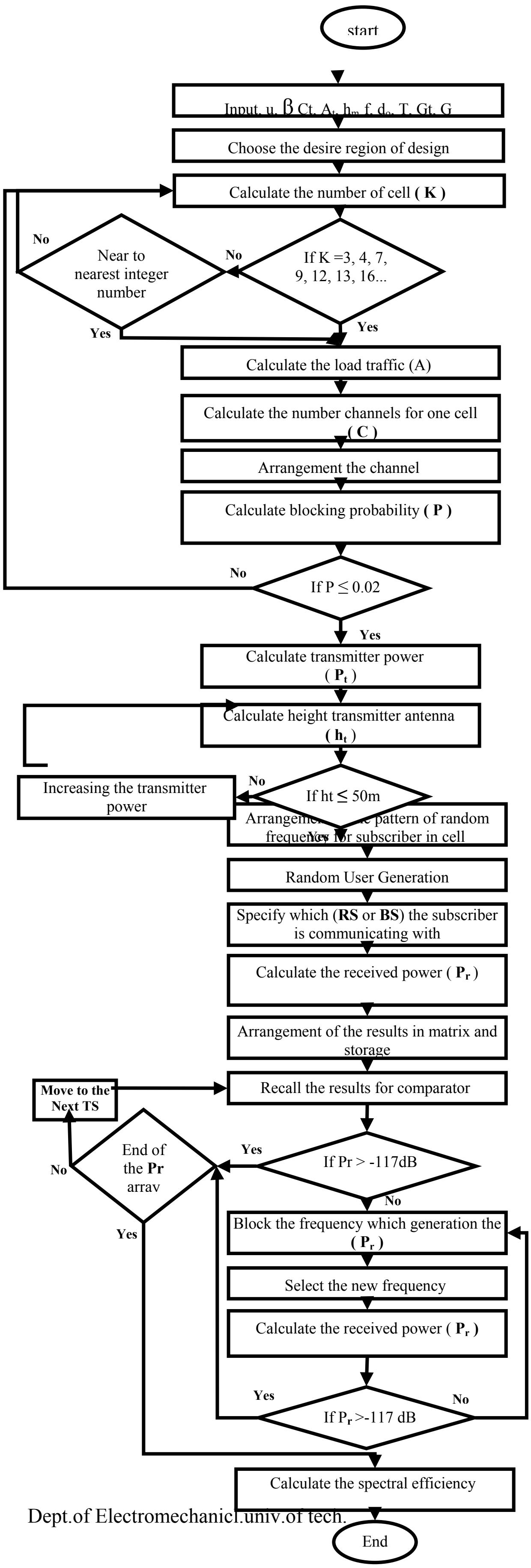


Figure (1) Simulation flowcharts for DFH

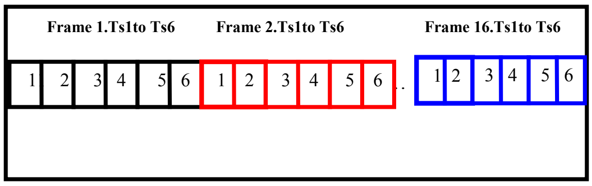


Figure (2) Ms is monitored over 96 time slots (time frames) for FH system

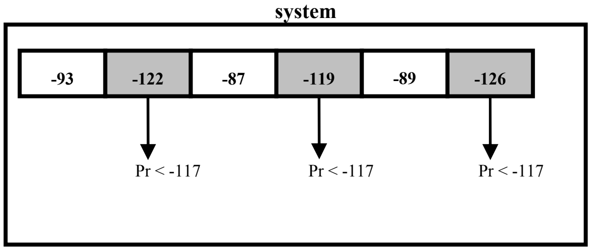


Figure (3) illustrates weak hop ratio for

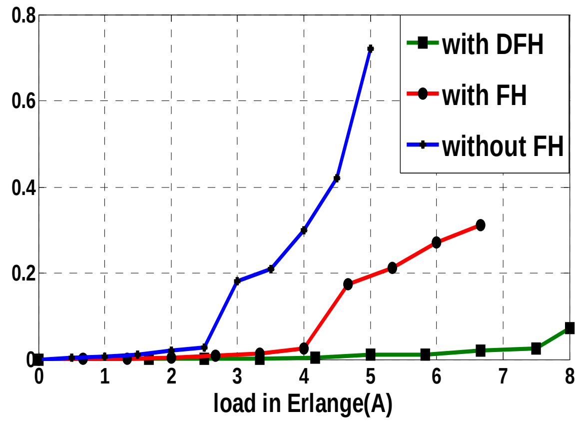


Figure (4) illustrates the relaionship between

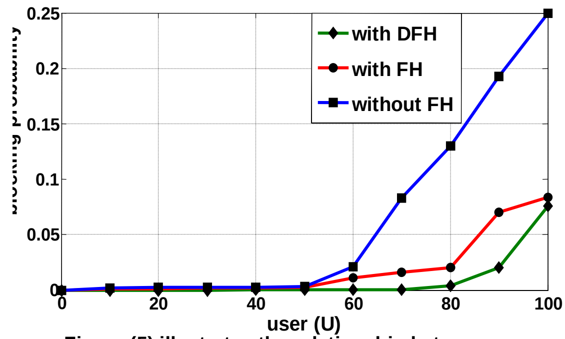


Figure (5) illustrates the relationship between blocking probability and users

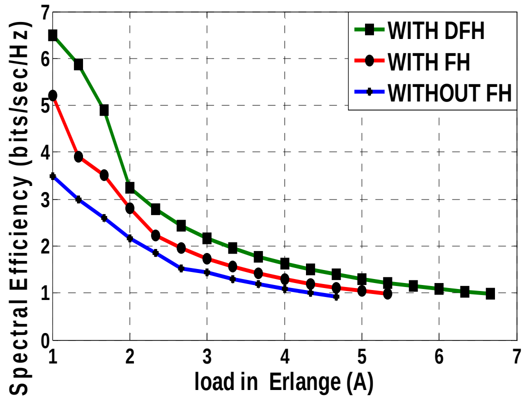
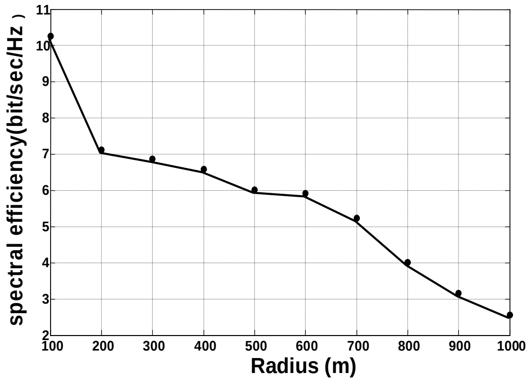
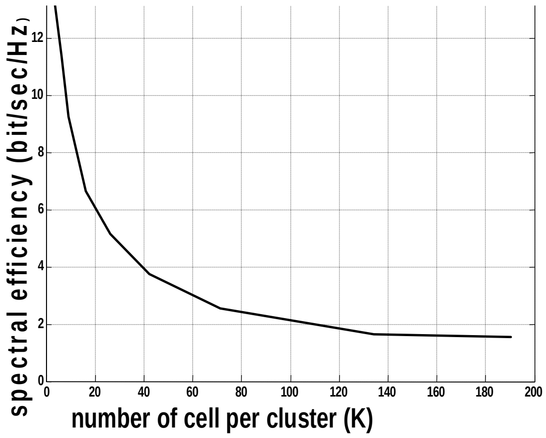


Figure (6) illustrates the relationship between the spectral efficiencyin(bit/s/Hz) with load



Fig(7):- illustrates the relationship between the spectral efficiency(bit/sec/Hz) and radius (m)



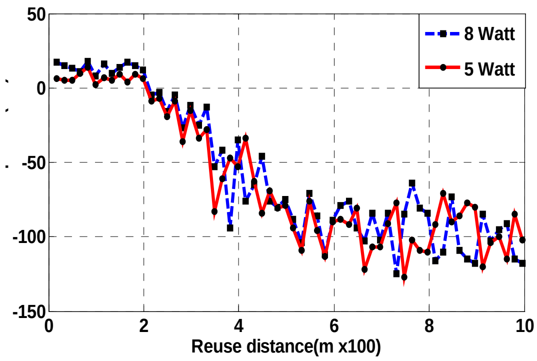


Figure (9) Received power in dB depends on the transmitted power with reuse distance (GSM without FH technique)

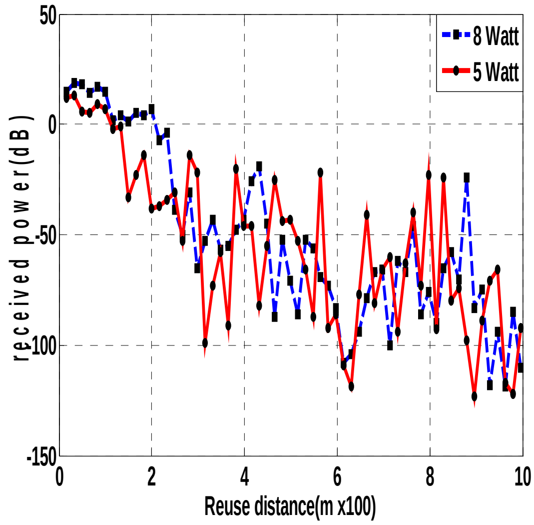


Figure (10) Received power in dB depends on the transmitted power with reuse distance (using FH technique)

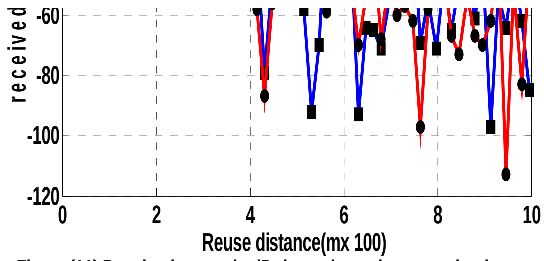


Figure (11) Received power in dB depends on the transmitted power with reuse distance (Using DFH Technique) .

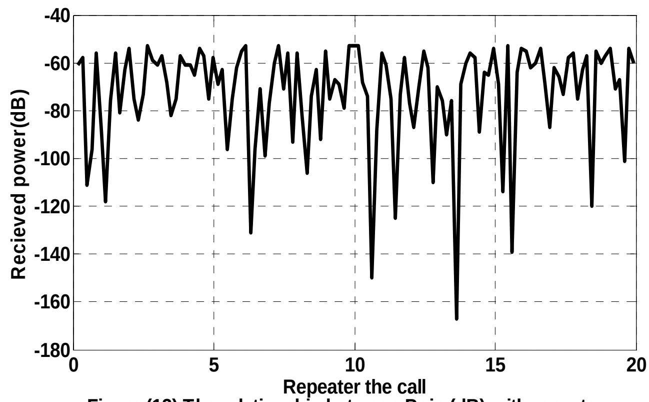


Figure (12) The relationship between Pr in (dB) with repeater call (without FH)

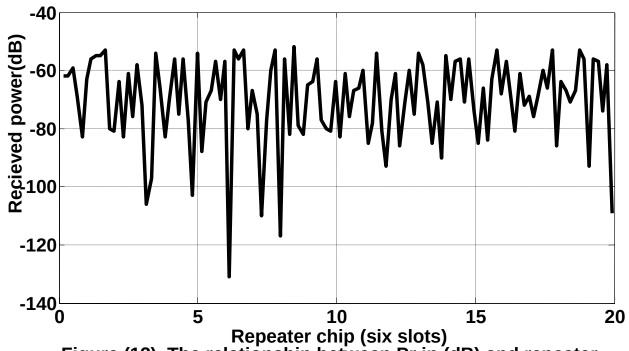


Figure (13) The relationship between Pr in (dB) and repeater chip (with FH)

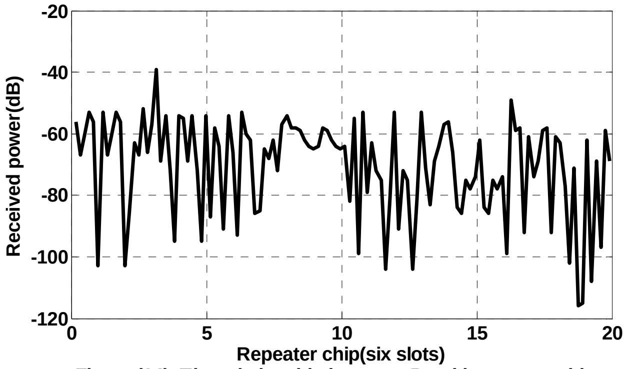


Figure (14) The relationship between Pr with repeater chip (with DFH Technique)