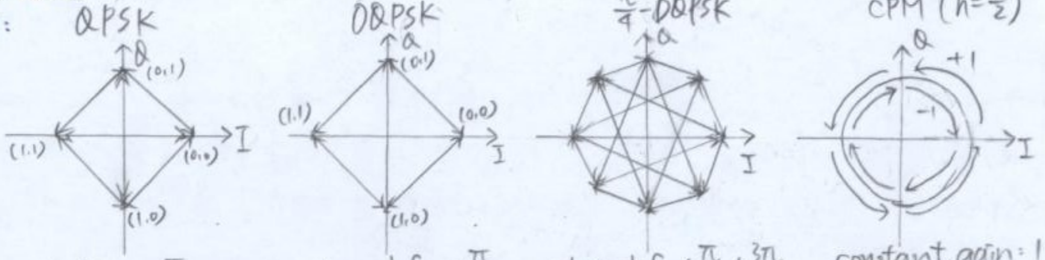
無線通訊系統期末

1. QPSK, OQPSK, $\frac{\pi}{4}$-DQPSK, CPM

(a) Draw

<sol>:



QPSK	OQPSK	$\frac{\pi}{4}$-DQPSK	CPM
phase shift: $\pm\frac{\pi}{2}$, $\pm\pi$	phase shift: $\pm\frac{\pi}{2}$	phase shift: $\pm\frac{\pi}{4}$, $\pm\frac{3\pi}{4}$	constant gain: 1
cross origin	No cross origin	No cross origin	phase shift: $\pm\frac{\pi}{2}$

#

(b) 比較 Linearity and dynamic range requirements of PA:

<sol>: 根據 phase trajectory 是否經過原點判斷: 越近原點 ⇒ PAPR↑, 對線性区敏感度↑。由(a)可知 QPSK 的 phase trajectory (PT) 有經过原点, 因此 envelope 变動性會很大, 造成 PA 需要有較高 linearity。另外 OQPSK 和 $\frac{\pi}{4}$-DQPSK 的 PT 都沒有経过原点, dynamic range 相較於 QPSK 小, 因此 PA 所需 linearity 較低, 又 $\frac{\pi}{4}$-DQPSK 的 PT 較 OQPSK 接近原点, 因此 $\frac{\pi}{4}$-DQPSK 所需的 linearity 較 OQPSK 大。而 CPM 之 PT 是繞著圓行走, 即 envelope 為 constant, 所以 dynamic range 相較於其他三種極小, 所需之 linearity 極低。

∴ requirement: QPSK > $\frac{\pi}{4}$-DQPSK > OQPSK > CPM #

(c) 為何 $\frac{\pi}{4}$-DQPSK 和 CPM 易於做 carrier phase synchronization, 而 QPSK 及 OQPSK 不易於做?

<sol>: 因為 $\frac{\pi}{4}$-DQPSK 和 CPM 之調變是以相位差來做, 所以不需要參考相位即可做同步, 而 QPSK 和 OQPSK 是以不同相位為一個 symbol, 所以需要參考相位才能做同步 (coherent modulation),

∴ $\frac{\pi}{4}$-DQPSK 及 CPM 較 QPSK 及 OQPSK 易做同步。

(d) Symbol-interval synchronization

<sol>: $\frac{\pi}{4}$-DQPSK 和 CPM: 每 T 個時間 phase 一定會改变, 因此易於作 symbol-interval synchronization.

QPSK, OQPSK: 每 T 個時間 phase 不一定會变化 (ex: input 連續相同), 較不易做 symbol interval synchronization.

#

(e)

<sol>: 若使用 high order modulation schemes (ex: 16QAM, 64QAM), 需要知道 channel 的 magnitude and phase information。

2. 關於 FSK

<sol>: $s(t)=\cos(2\pi f_c t+\phi(t))$

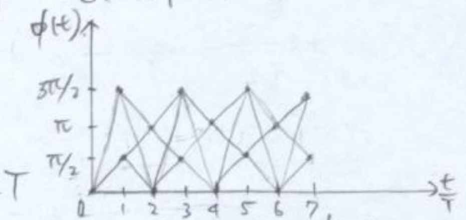
where $\phi(t)=\pi h\sum_{k=0}^{n-1}x_k+2\pi h x_n\beta(t-nT)$

$$h=\frac{1}{2},\quad \beta(t)=\begin{cases}0, & t<0\\ \frac{t}{2T}, & 0\le t\le T\\ \frac{1}{2}, & t>T\end{cases}$$

$$=\frac{\pi}{2}\sum_{k=0}^{n-1}x_k+\pi x_n\frac{t-nT}{2T},\quad 0\le t\le T$$

$$=\frac{\pi}{2}\sum_{k=0}^{n-1}x_k+\frac{\pi t}{2T}x_n-\frac{\pi n}{2}x_n,\quad 0\le t\le T$$

Excess phase:



$\phi_c(t)=2\pi f_c t+\phi(t)$

$$\Rightarrow s(t)=A\cos\left(2\pi f_c t+\frac{\pi}{2}\sum_{k=0}^{n-1}x_k+\pi x_n\frac{t-nT}{2T}\right)$$

$$=A\cos\left(2\pi\left(f_c+\frac{x_n}{4T}\right)t+\frac{\pi}{2}\sum_{k=0}^{n-1}x_k-\frac{n}{2}\pi x_n\right),\quad nT\le t\le(n+1)T$$

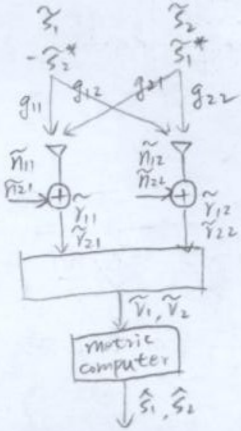
∴ when $x_n=1$, $f=f_c+\frac{1}{4T}$

$x_n=-1$, $f=f_c-\frac{1}{4T}$ $\qquad \Delta f=\frac{1}{2T}$

∴ MSK can be regarded as a type of FSK #

3. Show that space time diversity scheme is equivalent to MRC. (L=4)

<sol>:



$$\tilde{\gamma}=\tilde{s}\,g+\tilde{n}$$

$$=\begin{bmatrix}\tilde{s}_1 & \tilde{s}_2\\ -\tilde{s}_2^* & \tilde{s}_1^*\end{bmatrix}\begin{bmatrix}g_{11} & g_{12}\\ g_{21} & g_{22}\end{bmatrix}+\begin{bmatrix}\tilde{n}_{11} & \tilde{n}_{12}\\ \tilde{n}_{21} & \tilde{n}_{22}\end{bmatrix}$$

$$=\begin{bmatrix}g_{11}\tilde{s}_1+g_{21}\tilde{s}_2+\tilde{n}_{11} & g_{12}\tilde{s}_1+g_{22}\tilde{s}_2+\tilde{n}_{12}\\ -g_{11}\tilde{s}_2^*+g_{21}\tilde{s}_1^*+\tilde{n}_{21} & -g_{12}\tilde{s}_2^*+g_{22}\tilde{s}_1^*+\tilde{n}_{22}\end{bmatrix}$$

$$=\begin{bmatrix}\tilde{\gamma}_{11} & \tilde{\gamma}_{12}\\ \tilde{\gamma}_{21} & \tilde{\gamma}_{22}\end{bmatrix}$$

(cont.)

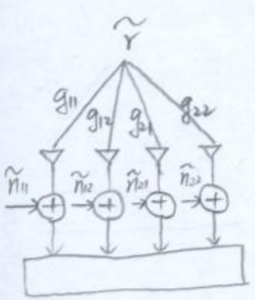
$\tilde{v}_1 = g_{11}^*\tilde{r}_{11} + g_{12}^*\tilde{r}_{12} + g_{21}\tilde{r}_{21}^* + g_{22}\tilde{r}_{22}^*$

$= (|g_{11}|^2+|g_{12}|^2+|g_{21}|^2+|g_{22}|^2)\tilde{s}_1 + g_{11}^*\tilde{n}_{11} + g_{12}^*\tilde{n}_{12} + g_{21}\tilde{n}_{21}^* + g_{22}\tilde{n}_{22}^*$

$\tilde{v}_2 = g_{21}^*\tilde{r}_{11} + g_{22}^*\tilde{r}_{12} + g_{11}\tilde{r}_{21}^* + g_{12}\tilde{r}_{22}^*$

$= (|g_{21}|^2+|g_{22}|^2+|g_{11}|^2+|g_{12}|^2)\tilde{s}_2 + g_{21}^*\tilde{n}_{11} + g_{22}\tilde{n}_{12}^* - g_{11}\tilde{n}_{21}^* + g_{12}\tilde{n}_{22}^*$

MRC:



$\tilde{r} = g\tilde{s} + \tilde{n}$

$\tilde{u} = g^*\cdot\tilde{r} = |g|^2\tilde{s} + g^*\tilde{n}$

$\tilde{u}_1 = (|g_{11}|^2+|g_{12}|^2+|g_{21}|^2+|g_{22}|^2)\tilde{s}_1 + g_{11}^*\tilde{n}_{11} + g_{12}^*\tilde{n}_{12} + g_{21}^*\tilde{n}_{21} + g_{22}^*\tilde{n}_{22}$

$\tilde{u}_2 = (|g_{11}|^2+|g_{12}|^2+|g_{21}|^2+|g_{22}|^2)\tilde{s}_2 + g_{11}^*\tilde{n}_{11} + g_{12}^*\tilde{n}_{12} + g_{21}^*\tilde{n}_{21} + g_{22}^*\tilde{n}_{22}$

∵ noise 作 phase rotation 並不影响

↓來開較有些不見!

∴ $\tilde{v}_1 = \tilde{u}_1$

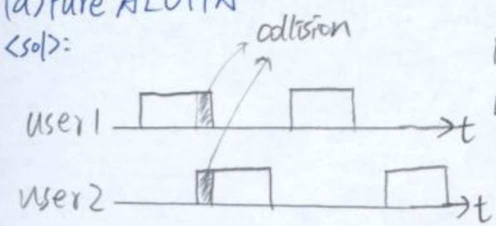
$\tilde{v}_2 = \tilde{u}_2$

⇒ Space-time diversity scheme is equivalent to MRC with diversity branches L=4 #

4. 解釋以下名詞

(a) Pure ALOHA

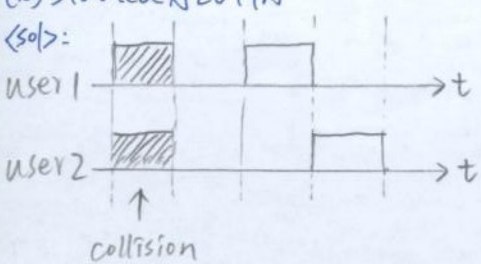
<sol>:



MS可隨時傳送,當collision發生時,user會等一個random backoff time後再傳。為最簡單的random access scheme。有feedback機制來acknowledge傳輸成功與否。

(b) Slotted ALOHA

<sol>:



當user要送packets時,一定要在每個time slot的開端傳送,當collision發生時,user會等一個random backoff time,然後在time slot開端重傳。有feedback機制來acknowledge傳輸成功與否。

(c) p-persistant CSMA:

<sol>: 當user有packets要送時,會先聽看看channel是否有別的user在作transmission,如果有的話,user會持續sense和等待直到channel变idle時,user會有$p(0\le p\le 1)$的機率傳送,$1-p$的機率random backoff。

(d) Non-persistent CSMA:

<sol>: 當user聽到channel有別的user在傳時,會直接defers一個random backoff time後再聽。

5. 計算reuse factor N的minimal. $M_\Lambda = 7dB$, $\Lambda_{th} = 9dB$

(a) Before cell sectoring.

<sol>: $M_\Lambda = \mu_\Lambda - \Lambda_{th} \Rightarrow \mu_\Lambda = M_\Lambda + \Lambda_{th} = 16dB \approx 40$

$L(d) = L(d_0) - 10\beta\log_{10}\left(\frac{d}{d_0}\right) = L(d_0) - 40\log_{10}\left(\frac{d}{d_0}\right)$ ∴ $\beta = 4$

$40 \le \frac{1}{2}\frac{1}{(\frac{D}{R}-1)^{-4}+(\frac{D}{R})^{-4}+(\frac{D}{R}+1)^{-4}} \approx \frac{1}{2}\frac{1}{3(\frac{D}{R})^{-4}}$ $\frac{D}{R}=\sqrt{3N}$

$\left(\frac{D}{R}\right)^{-4} \le \frac{1}{240} \Rightarrow 9N^2 \ge 240$, $N^2 \ge \frac{240}{9} \approx 26.....$

$N = i^2 + i\times j + j^2$, $i,j\in Z \Rightarrow N = 1,3,4,7,\cdots$

∴ $N \ge 5 \Rightarrow N_{min} = 7$ #

(b) After Cell sectoring

$40 \le \frac{1}{(\frac{D}{R})^{-4}+(\frac{D}{R}+0.7)^{-4}} \approx \frac{1}{2(\frac{D}{R})^{-4}}$

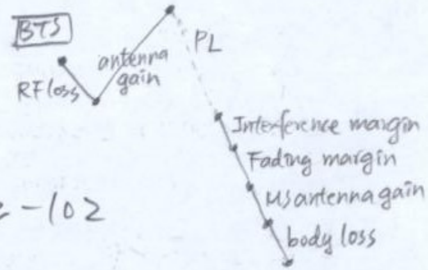
$\left(\frac{D}{R}\right)^{-4} \le \frac{1}{80} \Rightarrow 9N^2 \ge 80$, $N^2 \ge \frac{80}{9} \approx 8.....$

∴ $N \ge 3 \Rightarrow N_{min} = 3$ #

6. Link Budget Problem

(a) Forward link (BS→MS)

<sol>: ※不用管 dB or dBm



Tx power (BTS): 45 dBm

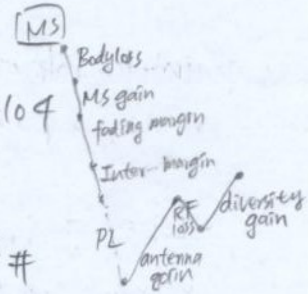
$$45-3+18-PL-2.5-5.5-3-2 \geq -102$$

$$PL \leq 47+102 = 149$$

∴ The maximum allowable PL is 149 dB #

(b) Reverse link (MS→BS)

<sol>:



$$33-3-2-5.5-2.5-PL+18-3+2 \geq -104$$

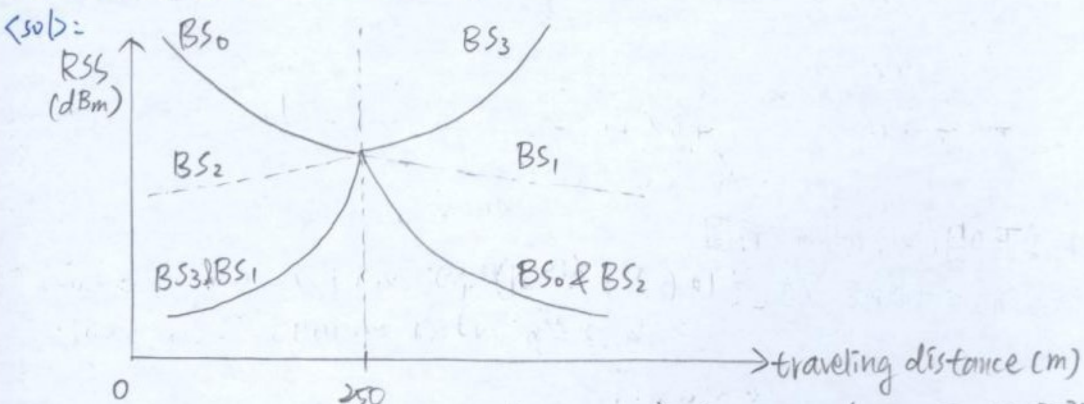
$$PL \leq 141$$

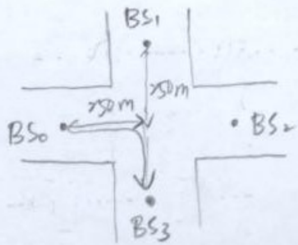
∴ The maximum allowable PL is 141 dB #

7. Handoff in street microcellular system

(a) Draw RSS v.s. Traveling distance

<sol>:





當逐漸接近250m時,BS_0逐漸衰弱而BS_1逐漸增強,但超過250m時,因corner effect關係,BS_0和BS_2開始大幅衰減而BS_3大幅增加,BS_1則稍微衰減。

(b) 比較 RSS 及 CIR based Handoff (Link quality problem)

<sol>: $RSS = C + I + N$

- C: carrier power
- I: interference power
- N: noise power

① 當RSS大時,可能為I+N很大而C較小,表示實際上quality很差。

② 當RSS小時,可能為I+N很小而C較大,表示實際上quality並不會太差。

∴用RSS判斷雖簡單但較易出錯

$CIR = \frac{C}{I+N}$ 由訊號功率與雜訊(包含干擾)之比率來判斷,雖可以較精準判斷是否要做handoff,但其algorithm的複雜度相對較高。(要decode and demodulate)

8. Guard channel and Handoff queuing (Two possible schemes adopt handoff priority to reduce the prob. of forced termination.)

(a) 名詞解釋

<sol>:

Guard channel: BS會預留一些channel專門用於handoff,一般call不能使用

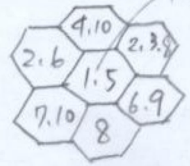
Handoff queuing: 當MS要做handoff但target BS沒有idle channel可用時,MS會先繼續和原先的serving BS維持radio link,且將handoff request放入queue (in the target BS).

(b) 優缺點:

<sol>: 上述2個方法皆可減少dropped calls的機率。Guard channel會使得BS可提供給new call的channel數減少,因此導致new call blocking probability增加。Handoff queuing則是因有handoff訊息排隊,可能使一些new call得不到channel,但其所造成的new call blocking probability只會稍微增加。

9.Cetralized DCA-MP(3-cell reuse, total 10 channels)

最多可以再增加幾個user到target cell?



<sol>:

$CL_1(A,B,T) = 1,2,3,4,5,8,10 \Rightarrow$ 空channel 6,7,9

$CL_2(B,C,T) = 1,2,3,5,6,8,9 \Rightarrow 4,7,10$

$CL_3(C,D,T) = 1,5,6,8,9 \Rightarrow 2,3,4,7,10$

$CL_4(D,E,T) = 1,5,7,8,10 \Rightarrow 2,3,4,6,9$

$CL_5(E,F,T) = 1,2,5,6,7,10 \Rightarrow 3,4,8,9$

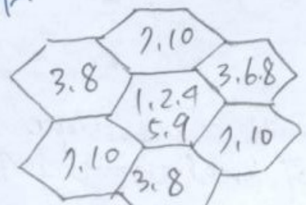
$CL_6(A,F,T) = 1,2,4,5,6,10 \Rightarrow 3,7,8,9$

∵一個cluster至多有7個channel (∵ tatal channel = 10)

∴最多可以再增加3個users #

(b) Draw the new channel assignment

<sol>:



N=3

A: 4→7, 和E,C為co-channel

C: (6,9)→(7,10)

B: 2→6

∵B和F,D為co-channel

∴F: (2,6)→(3,8)

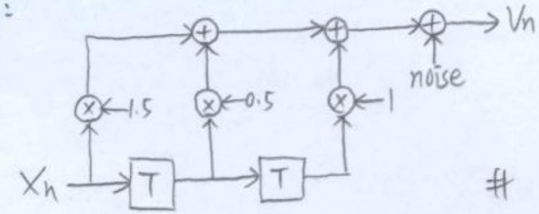
∴空出channel 2,4,9給target cell

#

10. Suppose that a binary sequence X, $X_n \in \{-1,+1\}$, is transmitted over an ISI channel with the channel gain vector $g=(1.5, 0.5, 1)$ and the initial state (-1,-1).

(a) Illustrate the channel model by using a transversal filter.

<sol>:



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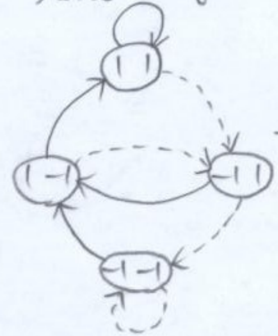
(b) Illustrate the state and trellis diagrams for an MLSE receiver.

<sol>:

state diagram



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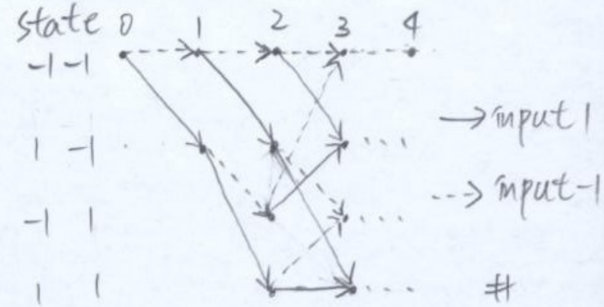
trellis diagram



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(c) Explain the role of training sequences for MLSE receivers.

<sol>: training sequence主要用來估測channel gain, 因training sequence是一個fixed pattern sequence, 因此接收端可利用經過channel的training sequence和原始的training sequence用adaptive filter去估出channel gain。

(d) What is the impact of the training sequence length for TDMA mobile?

<sol>: training sequence越長, 估測越準, 但浪費頻寬
training sequence越短, 估測較不準, 會使在destination發生錯誤, 但較節省頻寬。
For TDMA systems, the training sequence should be transmitted in each slot.

11. 証明(2013 Problem 5有圖)

(a) Show that $C/I = 10\beta \log\left(\frac{D}{R}-1\right)$

<sol>: $\frac{C}{I} = \mu_\Omega(R) - \mu_\Omega(D-R)$

$= \underbrace{\mu_\Omega(d_0) - 10\beta\log_{10}\frac{R}{d_0}}_{\text{received Power for desired BS}} - \underbrace{\left(\mu_\Omega(d_0) - 10\beta\log_{10}\frac{D-R}{d_0}\right)}_{\text{received Power for interfering BS}}$

$= 10\beta\log_{10}\left(\frac{D}{R}-1\right)$ #

(b) Derive the probability of CCI outage.

<sol>: $N_I = 1$

$\Lambda_{\Omega(dB)}(d)$ 之 mean 為 $\mu_{\Lambda(dB)}(d) = \mu_{\Omega}(d_0) - \mu_{\Omega}(d_1)$

variance $\sigma_\Lambda^2 = \sigma_\Omega^2 + \sigma_\Omega^2 = 2\sigma_\Omega^2$

為高斯分布

$$\Rightarrow O(d) = P_r\left(\Lambda_{\Omega(dB)}(d) < \Lambda_{th(dB)}\right)$$

$$= \int_{-\infty}^{\Lambda_{th(dB)}} \frac{1}{\sqrt{2\pi}\,\sigma_\Omega} e^{-\frac{(x-\mu_\Lambda)^2}{2\sigma_\Omega^2}} dx = Q\left(\frac{\mu_\Lambda(d) - \Lambda_{th(dB)}}{\sqrt{2}\,\sigma_\Omega}\right)$$

$$= Q\left(\frac{10\log_{10}\left(\frac{D}{R}-1\right)^\beta - \Lambda_{th(dB)}}{\sqrt{2}\,\sigma_\Omega}\right) \#$$

$$* O_I(d) = P_r\left(\Lambda_{(dB)}(d) < \Lambda_{th(dB)}\right) = Q\left(\frac{\mu_{\Omega(dB)}(d_0) - \mu_{\Xi(dB)}(d_1) - \Lambda_{th(dB)}}{\sqrt{\sigma_\Omega^2 + \sigma_\Xi^2}}\right)$$

(c) Derive reuse factor N.

<sol>:

$$M_\Lambda = \mu_\Omega(R) - \mu_\Omega(D-R) - \Lambda_{th} = \mu_\Lambda(R) - \Lambda_{th}$$

$$= 10\beta\log_{10}\left(\frac{D}{R}-1\right) - \Lambda_{th} = 10\beta\log_{10}\left(\sqrt{3N}-1\right) - \Lambda_{th}$$

$$\sqrt{3N} = 10^{\frac{M_\Lambda + \Lambda_{th}}{10\beta}} + 1 \qquad N = i^2 + i \times j + j^2$$

$$N = \frac{1}{3}\left[10^{\frac{M_\Lambda + \Lambda_{th}}{10\beta}} + 1\right]^2 \#$$

12. 解釋

(a) Explain NCHO, MAHO, MCHO

<sol>:

NCHO: 1. Serving cell 會去 monitor MS 的 signal, 並 detect MS 是否在 cell boundary.
2. 鄰近的 cells 也會 monitor MS 的 signal, 並回傳狀況給 network.
3. Network controller 會選一個最好的 cell, for handoff, 並選一個 frequency channel 給 MS.
4. Network 通知 MS handoff 到新的 frequency channel #

MAHO: 1. MS 會 monitor 鄰近 cell 的 signal 並回傳給 serving cell
2. Serving cell 會根據回傳訊息去 detect MS 是否在 cell boundary.
3. Network 根據 MS 回傳的訊息選一個最好的 cell for handoff 並選一個 frequency channel 給 MS.
4. Network 通知 MS handoff 到新的 frequency channel. #

MCHO: 1. MS 會 monitor 鄰近 cell 的 signal
2. MS 偵測到鄰近 cell 的 quality 較其 serving cell 好
3. MS 選一個新的 frequency channel 並 access 到 cell.
4. Cell 接受 MS, 成為 MS 新的 serving cell.
5. 新的 serving cell 通知舊的 serving cell 中斷和 MS 間的 link. #

(b) Compare NCHO, MAHO, MCHO

<sol>: NCHO 由 BS (neighboring cell) 偵測功率, MAHO 及 MCHO 則是由 MS 偵測。NCHO 及 MAHO 由 Network controller 作決定, MCHO 則是由 MS 自行作決定。 #

(c) Why MAHO can't be used in FDMA?

<sol>: 在 FDMA 系統中, MS 只有一個 transceiver, 因此 MS 無法同時 monitor 鄰近 cell 的 signal 和連續傳送 info。 #

13. The two branch SSC scheme with 2 uncorrelated branches, the switching threshold is T, the average received ENR for each diversity branch is $\bar{\gamma}_c$, and the distribution of the received ENR is $P_{\gamma_k}(x) = \frac{1}{\bar{\gamma}_c} e^{-x/\bar{\gamma}_c}$

(a) Determine the probability q that the received ENR in a specific branch is below the threshold T.

<sol>: $q = P_r[\gamma_i < T] = \int_{-\infty}^{T} \frac{1}{\bar{\gamma}_c} e^{-x/\bar{\gamma}_c} dx = 1 - e^{-T/\bar{\gamma}_c}$ #

(b) If the probability that the received ENR in a specific branch is below a value S is p, determine the probability that the ENR at output of the switched combiner is below S, i.e. $P_r[\gamma_s^{sw} \le S]$, for $S < T$ and $S \ge T$.

<sol>: $p = P_r[\gamma_i \le S] = 1 - e^{-S/\bar{\gamma}_c}$ Assume branch 1 is in use

$$P_r[\gamma_s^{sw} \le S] = P_r[\gamma_s^{sw} \le S \mid \gamma_s^{sw} = \gamma_1] \cup P_r[\gamma_s^{sw} \le S \mid \gamma_s^{sw} = \gamma_2]$$

$$= \begin{cases} P_r[\{\gamma_1 < T\} \cap \{\gamma_2 \le S\}], & S < T \\ P_r[\{T \le \gamma_1 \le S\} \cup \{\gamma_1 < T \cap \gamma_2 \le S\}], & S \ge T \end{cases}$$

(γ_1, γ_2 are independent)

不懂QQ

$$= \begin{cases} qp, & S < T \\ (p - q) + qp, & S \ge T \end{cases} \#$$

14. Diversity Combining Techniques: SC, MRC, EGC, SW

(a) Explain and Compare (complexity, performance, …) the four.

<sol>: SC: Selective Combining, 選擇有最大SNR的branch.

MRC: Maximal Ratio Combining, the diversity branches must be weighted by their respective complex fading gains and then combined.

EGC: Equal Gain Combining, is similar to MRC, but the diversity branches are not weighted (phase info is still required) and is useful for the modulation techniques having equal energy symbols.

SW: Switched Combining, a switch combiner scans through the diversity branches until it finds one that has a SNR exceeding a specified threshold.

#

① Performance: MRC > EGC > SC > SW

MRC: $gain^2$, 去掉phase, 全部branch相加

EGC: 去掉phase, branch相加

SC: Select the branch with max SNR

SW: 當所在的branch的gain低於threshold, 換到另一個branch.

② Complexity: MRC > EGC > SC

MRC: 考慮gain & phase

EGC: 考慮phase

SC: just choose max. SNR branch

③ required information:

MRC: channel gain and phase

EGC: channel phase

SC: SNR

SW: channel gain

(b) Show that the average symbol ENR with MRC is $\bar{\gamma}_s^{MRC} = \sum_{k=1}^{L} \bar{\gamma}_k$, where $\bar{\gamma}_k$ is the average symbol ENR of the k-th branch and L is the number of the diversity branches.

<sol>: $\alpha_c = \sum_{k=1}^{L} \alpha_k^2$, α_k is the channel gain

$\sigma_{n,tot}^2 = N_0 \sum_{k=1}^{L} \alpha_k^2$ (Assume all branches have the same noise power)

$$\Rightarrow \gamma_s^{MRC} = \frac{\alpha_c^2 E_{av}}{\sigma_{n,tot}^2} = \frac{\sum_{k=1}^{L} \alpha_k^2 \sum_{j=1}^{L} \alpha_j^2 \, E_{av}}{N_0 \cdot \sum_{j=1}^{L} \alpha_j^2} = \sum_{k=1}^{L} \frac{\alpha_k^2 E_{av}}{N_0} = \sum_{k=1}^{L} \gamma_k \#$$

where E_{av} is the average received symbol energy

15. 解釋

(1) Space diversity

<sol>: 利用multiple receive antennas來達成。通常antennas要相距夠遠使得correlation coefficiency夠小, 來得到diversity。由於antenna要相距很遠, 因此通常用於BS。# ($\ge 10\lambda_c$)

(b) Angle diversity

<sol>: 利用directional antennas來達成。每根天線會選擇從narrow range of angles來的plane wave。缺點是每根天線有side lobe影响其他天線造成干擾。 #

(c) Polarization diversity

<sol>: 利用極化方向不同來達成。Scattering環境可以depolarize a signal, 若環境無法depolarize signal, 則有些天線會收不到訊號。(urban area: polar. or space; open area: space only) #

(d) Frequency diversity

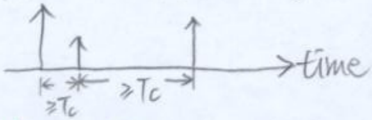
<sol>: 利用multiple frequency channel來達成，channel間隔要大於channel的coherence bandwidth才不會有干擾。(較不受車速影響，但在低速環境中，fade duration長，整体performance差。) #

(e) Field diversity

<sol>: 利用电場和磁場達成，电場和磁場的components are uncorrelated at any point. #

(f) Multipath diversity

<sol>: Resolving multipath components at different delays. Time resolution must be high enough.



T_c: chip duration #

(g) Time diversity

<sol>: Tx or Rx端在不同時間傳送和接收data，time slots間隔至少大於channel的coherence time。利用時間不同，channel特性不同而獲得diversity。不適在高速環境實現，因channel變化太快。 #

16. Sequence estimators are generally offer better performance in mitigating the effect of ISI.

(a) Explain the MLSE receiver concept.

<sol>: ① Make decisions on sequences of the received symbols.

② After receiving the seq. $\{V_n\}_{n=1}^{k}$, the ML receiver decides in favor of the seq. $\{x_n\}_{n=1}^{k}$ that maximizes the likelihood func. or log-likelihood func. $p(V_k,\cdots,V_1 \mid x_k,\cdots,x_1)$, $\log P(V_k,\cdots,V_1 \mid x_k,\cdots,x_1)$

③ To implement the ML receiver by searching through trellis (N_s-states) for most likely transmitted sequence x.

(b) Explain the Viterbi algorithm.

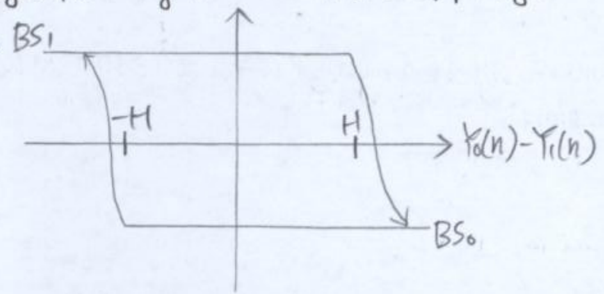
<sol>: The viterbi Algorithm can be used to implement the ML receiver by searching through the N_s-state trellis for most likely transmitted sequence x. (searching process即為MLSE)

17. Explain what is Handoff and why is it so important?

<sol>: 當MS移動時，其由serving BS轉換至另一個BS的過程即為Handoff。因BS的coverage有限且MS會移動，因此Handoff是必需的。 #

18. Signal strength based Handoff algorithms

<sol>:



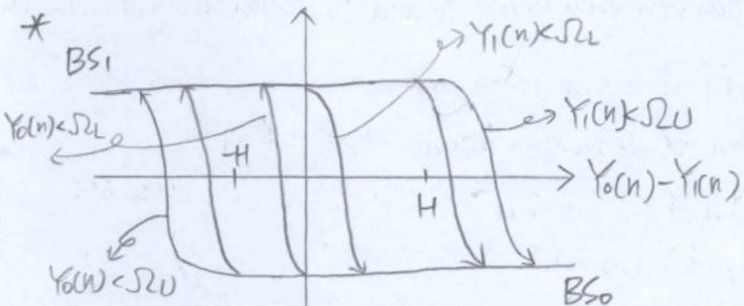
H: hysteresis (dB)

$Y_0(n)$ and $Y_1(n)$: estimated signal strength (dBm) of BS_0 and BS_1

$$\begin{cases} Y_1(n) > Y_0(n) + H & : BS_0 \rightarrow BS_1 \\ Y_0(n) > Y_1(n) + H & : BS_1 \rightarrow BS_0 \end{cases}$$

* The purpose of using hysteresis is to reduce ping-pong effect.
* Ping-pong effect: 由於fading channel的影响，使得MS一直作Handoff.

*



超过Ω_U: 不作Handoff

低於Ω_L: 作Handoff #

19. To improve system performance, each cell can be devided into an inner cell and an outer cell. Channels are assigned to the inner and outer cells according to 4-cell and 7-cell frequency reuse plans, respectively. The radius of the outer cells is assumed to be R_0.

(a) Find the maximum acceptable radius R_i of the inner cells.

<sol>: $\frac{D_i}{R_i} = \frac{D_0}{R_0} = \sqrt{3\times7} = 4.6$

$D_i = \sqrt{3\times4}\,R_0 = \sqrt{12}\,R_0 = 4.6 R_i$

$\therefore R_i = (\sqrt{12}/4.6) R_0 \approx 0.75 R_0$ #

(b) According to the results obtained in (a), if the traffic distribution is homogeneous, find the ratio of the channel numbers assigned for the inner and outer cells.

<sol>: Area of an inner cell:

$$A_i = (0.75)^2 A_0 \approx 0.56 A_0$$

If N_c channels are available in a cell, the ratio of the channel numbers assigned for the inner and outer cells are:

$$\frac{\text{inner cell}}{\text{outer cell}} = \frac{0.56 N_c}{0.44 N_c} = \frac{14}{11} \quad \#$$

(c) Find the capacity improvement when compared with the system using the 7-cell frequency reuse plan.

<sol>: The number of total channel available in the system is:

$$N_T = (0.44 \times 7 + 0.56 \times 4) N_c = 5.32 N_c$$

If only the 7-cell reuse plan is used:

$$N_c' = \frac{N_T}{7} = 0.76 N_c$$

The capacity improvement:

$$\frac{(N_c - N_c')}{N_c'} = \frac{0.24}{0.76} \approx 32\% \quad \#$$

20. Assume that an MS is in the handoff region between BS_0 and BS_1 with the received signal strength being Y_0 and Y_1, respectively. H, H_e, H_d, Ω_U, Ω_L are applied.

(a) Illustrate the handoff algorithm with upper and lower threshold.

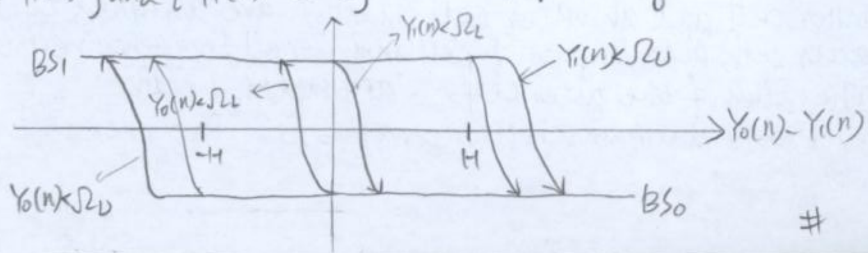
<sol>: A handoff is performed between BS_0 and BS_1, when:

$\{Y_1(n) > Y_0(n) + H\}$ and $\{\Omega_L < Y_0(n) < \Omega_U\}$, if serving BS is BS_0

$\{Y_1(n) > Y_0(n)\}$ and $\{Y_0(n) < \Omega_L\}$, if serving BS is BS_0

$\{Y_0(n) > Y_1(n) + H\}$ and $\{\Omega_L < Y_1(n) < \Omega_U\}$, if serving BS is BS_1

$\{Y_0(n) > Y_1(n)\}$ and $\{Y_1(n) < \Omega_L\}$, if serving BS is BS_1



\#

(b) Illustrate the handoff algorithm with moving direction bias.

<sol>: This algorithm incorporates the moving direction information into the handoff algorithm.

- To encourage handoff to BS that the MS is approaching
- To discourage handoff to BS that the MS is moving away.

A handoff is performed from BS_s to BS_j

- If $BS_j \in R$ $\quad Y_j(n) > X_s(n) + H$, if $BS_s \in R$

  $\quad Y_j(n) > X_s(n) + H_d$, if $BS_s \in A$

- If $BS_j \in A$ $\quad Y_j(n) > X_s(n) + H_e$, if $BS_s \in R$

  $\quad Y_j(n) > X_s(n) + H$, if $BS_s \in A$

Note that $H_e \le H \le H_d$ \#