行政院國家科學委員會專題研究計畫 成果報告

高速移動之多天線與多頻道無線通訊之通道模型與干擾控制之研究
研究成果報告(精簡版)

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中 華 民 國 101年11月06日

中 文 摘 要 ： 近年來，人們在無線網路上對於數據的高速傳送及其應用的大量需求，引起了新無線電技術的探討及新無線電系統如WiMAX、3GPP 和 LTE 之佈建。這些無線電系統都是在2.5GHz/3.5GHz 附近運作。近期在傳統應用於廣播電視的470 MHz 及 870 MHz 頻段隨著類比電視在此頻段的釋出，使得人們考量是否能將 WiMAX、3GPP 及 LTE 應用於此頻段內。主要的考量是它的路徑傳輸損失會比 2.5GHz 來的小同時它在室外-室內的傳送中可能也會有較低的穿透損失。
Femtocell 具有較低的發射功率，同時它是工作在需具有執照許可的頻段內利用寬頻將行動電話用戶與電信系統相聯結。使用 Femtocell 不但可以降低建置成本且具有高傳輸速率與極低功率消耗等優點。它在小型辦公室及家庭內的應用有著無限的潛能，也可能帶進目前的 3GPP、3GPP2、WiMAX 與 LTE-Advanced 系統並做技術的整合。
基本上本計畫為二年之工作計劃，其工作內容為(1)建立高速度(500 公里/時)、多頻帶、多載波、多天線系統的傳播損失通道模型、探討其干擾控制技術。特別是針對 700MHz 及2.5GHz/3.5GHz 二系統的傳輸特性做一詳細的比較。(2)建立700MHz 及 2.5G/3.5G 系統中 Femotcell 之傳播損失通道模型,穿透損失及 Macrocell - Femtocell 間之干擾模型及干擾源。探討減少或防止兩者間干擾之技術。(3)在不同的通信情境中如市區、郊區、家庭/辦公室等進行包括 Femtocell之 700MHz 及 2.5G/3.5G 之無線電 OFDM 系統效能模擬分析及比較。

中文關鍵詞： 毫微微蜂巢式基地台，大型基地台，高速度, 干擾模型, 傳輸損失，通路預算，干擾隨機化，干擾抵消，干擾協調, 頻率重用, 死寂區

英 文 摘 要 ： The demand for higher data rates and vast applications in wireless networks have triggered the development and design of new wireless technologies and the new system deployments such as WiMAX, 3GPP and LTE systems. These system developments are operated in around the 2.5 GHz frequency band. Lately the traditionally frequency band between 470 MHz and 862 MHz that originally allocated for radio and TV broadcasting services became available for other services and applications and has been considered its availability for use in the WiMAX, 3GPP or LTE systems. It has also been drawn attention that in this band it has low propagation loss and also possibly having lower penetration loss for outdoor-indoor propagation comparing to the allocated 2.5/3.5 GHz band. Femtocells are low-power wireless AP that operate in licensed spectrum and connect mobile devices to an operator’s network over broadband connections. Femtocells enable lower cost wireless broadband, high sustained data rates and lower power that potentially will revolutionize mobile network deployments within 3GPP, WiMAX, and LTE. Basically three tasks will be conducted in this study for a period of 2 years, (1) The development of propagation loss, channel model and interference mitigation technology for high speed (500 km/hr), multi-band, multi-carrier and MIMO wireless communication systems especially compare in detail the transmission characteristics between 700 MHz and 2.5/3.5 GHz systems, (2) The development of channel model, including propagation loss, penetration loss for Femtocell, the development of interference model between Femtocell and Macrocell and investigate the interference mitigation and avoidance technologies between them and (3) System performance evaluation and simulation for 700 MHz and 2.5GHz/3.5 GHz high mobility OFDM wireless communication systems, including the Femtocells deployment, in various communication environments such as urban, suburban and home/small office. Analyze and compare their system performances.

英文關鍵詞： Femtocell, Macrocell, high mobility, interference model, propagation loss, link budget, interference randomization, interference cancellation, interference coordination, frequency reuse, dead zone

高速移動之多天線與多頻道無線通訊之通道模型與干擾控制之研究

Channel Models and Interference Management for High Mobility, MIMO and Multiband Wireless Communication System

計劃編號: NSC：100-2221-E-032-031-

執行期間:100 年 08 月 01 日至 101 年 07 月 31 日

計劃主持人: 詹益光　　　　淡江大學電機工程學系教授

一、 計劃中文摘要(**關鍵詞：毫微微蜂巢式基地台，大型基地台，高速度，干擾模型，傳輸損失，通路預算，干擾隨機化，干擾抵消，干擾協調，頻率重用，死寂區**)

近年來，人們在無線網路上對於數據的高速傳送及其應用的大量需求，引起了新無線電技術的探討及新無線電系統如WiMAX、3GPP 和LTE 之佈建。這些無線電系統都是在2.5GHz/3.5GHz 附近運作。近期在傳統應用於廣播電視的470 MHz 及870 MHz 頻段隨著類比電視在此頻段的釋出，使得人們考量是否能將WiMAX、3GPP 及LTE 應用於此頻段內。主要的考量是它的路徑傳輸損失會比2.5GHz 來的小同時它在室外-室內的傳送中可能也會有較低的穿透損失。

Femtocell 具有較低的發射功率，同時它是工作在需具有執照許可的頻段內利用寬頻將行動電話用戶與電信系統相聯結。使用Femtocell 不但可以降低建置成本且具有高傳輸速率與極低功率消耗等優點。它在小型辦公室及家庭內的應用有著無限的潛能，也可能帶進目前的3GPP、3GPP2、WiMAX 與LTE-Advanced 系統並做技術的整合。

基本上本計畫為二年之工作計劃，其工作內容為(1)建立高速度(500 公里/時)、多頻帶、多載波、多天線系統的傳播損失通道模型、探討其干擾控制技術。特別是針對700MHz 及2.5GHz/3.5GHz 二系統的傳輸特性做一詳細的比較。(2)建立700MHz 及2.5G/3.5G 系統中Femotcell 之傳播損失通道模型,穿透損失及Macrocell - Femtocell 間之干擾模型及干擾源。探討減少或防止兩者間干擾之技術。(3)在不同的通信情境中如市區、郊區、家庭/辦公室等進行包括Femtocell 之700MHz 及2.5G/3.5G 之無線電OFDM系統效能模擬分析及比較。

英文摘要(Keywords：Femtocell, Macrocell, high mobility, interference model, propagation loss, link budget, interference randomization, interference cancellation, interference coordination, frequency reuse, dead zone)

The demand for higher data rates and vast applications in wireless networks have triggered the development and design of new wireless technologies and the new system deployments such as WiMAX, 3GPP and LTE systems. These system developments are operated in around the 2.5 GHz frequency band. Lately the traditionally frequency band between 470 MHz and 862 MHz that originally allocated for radio and TV broadcasting services became available for other services and applications and has been considered its availability for use in the WiMAX, 3GPP or LTE systems. It has also been drawn attention that in this band it has low propagation loss and also possibly having lower penetration loss for outdoor-indoor propagation comparing to the allocated 2.5/3.5 GHz band. Femtocells are low-power wireless AP that operate in licensed

spectrum and connect mobile devices to an operator's network over broadband connections. Femtocells enable lower cost wireless broadband, high sustained data rates and lower power that potentially will revolutionize mobile network deployments within 3GPP, WiMAX, and LTE. Basically three tasks will be conducted in this study for a period of 2 years, (1) The development of propagation loss, channel model and interference mitigation technology for high speed (500 km/hr), multi-band, multi-carrier and MIMO wireless communication systems especially compare in detail the transmission characteristics between 700 MHz and 2.5/3.5 GHz systems, (2) The development of channel model, including propagation loss, penetration loss for Femtocell, the development of interference model between Femtocell and Macrocell and investigate the interference mitigation and avoidance technologies between them and (3) System performance evaluation and simulation for 700 MHz and 2.5GHz/3.5 GHz high mobility OFDM wireless communication systems, including the Femtocells deployment, in various communication environments such as urban, suburban and home/small office. Analyze and compare their system performances.

二、計劃緣由與目的

隨著時代的進步，人們對於網路的應用需求愈來愈多元，服務品質要求也相對的提升，因此網路已經成現代生活不可或缺一部分，隨之而來問題就是如果想隨時隨地使用網路資源，早期的無線行動網路系統無法滿足現有需求，網路服務業者希望無線行動網路技術可以擁有更多的頻寬來傳輸以及擴展其寬頻網路的涵蓋範圍。3GPP (Third Generation Partnership Project)系統規範機構提出新的無線網路介面標準，都兼具有高傳輸速度、高頻寬與涵蓋範圍大等優點，使得使用者在全新的系統實際運作時的參數如何設定的問題接踵而來。

基於使用者若位於複數基地台之涵蓋範圍下，如圖 1 所示，當使用基地台協調合作技術，使用者受到複數基地台連線，可以使用 Co-MIMO、CoMP(Coordinated Multipoint)等技術來提升使用者接收之增益及降低干擾技術[13-15]，本論文將分析使用者若受到複數基地台之連線傳輸，基地台頻寬佔用情形，藉此來分析使用基地台協調合作技術之最佳時機。在圖中當 BS1 與 BS2 傳送資料使用不同的載波頻率時，UE 能根據 SNR 較高之訊號接收，使訊號品質較佳，反之 BS1 與 BS2 傳送資料使用相同的載波頻率時，UE 接收之訊號能有增益的提升。

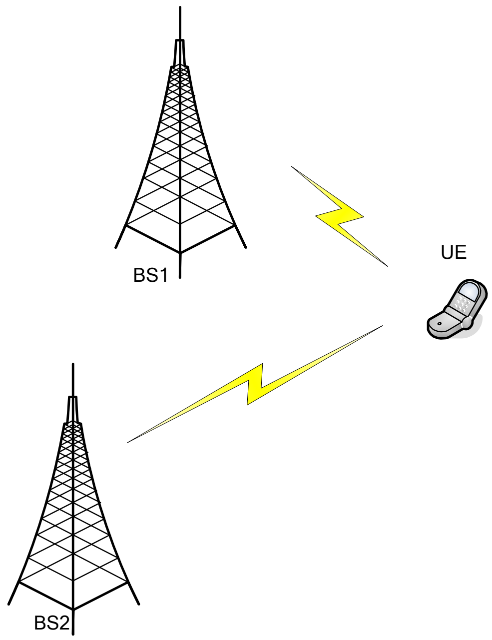

圖 1：UE 落在複數個基地台下示意圖

三、研究方法與成果

1.通道分析

1.1.通道模型

在無線通訊中通道衰減是很重要的影響因素，因為在傳送訊號經過無線通道可能會被許多因素所干擾，例如訊號經過建築物、樹林、丘陵反射所產生的多重路徑效應(Multipath Effect)，多重路徑使訊號衰減或放大，造成接收端無法正確判讀訊號。在無線通訊系統中，無

線通道模型通常是利用通道的統計特性分析與模擬，文獻已經提出相當多的通道模型，本研究提出路徑損失模型[4-12]模型來探討，使模擬更接近真實情況，式(1)是基地台或手機接收功率，

$$P(dBm) = P_t + G_t + G_r - PL \;\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

P_t ： 基地台/手機傳輸功率(dBm)

G_t ： 手機/基地台天線增益(dBi)

G_r ： 基地台/手機天線增益(dBi)

PL ： 路徑損失(dB)

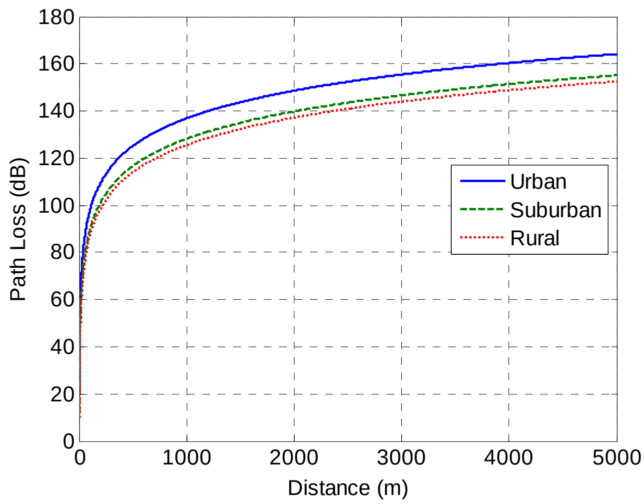

圖 2：路徑損失模擬

1.2.路徑損失模型

本研究使用之路徑損失模型(Path Loss)，是參照 3GPP Rel.9[1]而來，使用 Macro 基地台之路徑損失，使用 Non-Line Of Sign(NLOS)方程式如下式(2)：

$$PL = 161.04 - 7.1\log10(W) + 7.5\log10(h) - (24.37 - 3.7(h/h_{BS})2)\log10(h_{BS}) + (43.42 - 3.1\log10(h_{BS}))(\log10(d) - 3) + 20\log10(f_c) - (3.2(\log10(11.75h_{UT}))2 - 4.97) \;\ldots\ldots (2)$$

使用參數：

d=基地台與使用者之間距離，$10\text{ m} < d < 5000\text{ m}$

h = 平均建築物高度(meter)

W = 道路寬度(meter)， $5\text{ m} < h, W < 50\text{ m}$

h_{BS} = 基地台高度(meter)， $10\text{ m} < h_{BS} < 150\text{ m}$

h_{UT} = 使用者高度(meter)， $1\text{ m} < h_{UT} < 10\text{ m}$

f_c = 載波頻率(G Hz)

此路徑損失模型使用情境有三種：市區(Urban)、郊區(Suburban)、鄉村(Rural)，當載波頻率為 2GHz 時，路徑損失模型之模擬如圖 2 而這三種情境所定義之參數亦有所不同，所定義參數如下：

Urban Macro:

h_{BS} = 25 m, h_{UT} = 1.5 m, W = 20 m, h = 20 m

Suburban Macro:

h_{BS} = 35 m, h_{UT} = 1.5 m, W = 20 m, h = 10 m

Rural Macro:

h_{BS} = 35 m, h_{UT} = 1.5 m, W = 20 m, h = 5 m

1.3.訊雜比與距離分析

我們必須很清楚的知道基地台與接收端之間的最大距離來決定調變及編碼率，由傳送端及接收端之傳送距離可以決定接收端之 SNR 值[2]。雜訊功率可藉由如式(3)公式估算出。

$$N(dBm) = N_0 \times BW = kT_e \times BW = BW\frac{4.0pW}{GHz} \quad \ldots(3)$$

$$SNR(dB) = P(dBm) - N(dBm) \;\ldots\ldots\ldots\ldots\ldots (4)$$

$k = 1.38 \times 10^{-23}$ J/K (Boltzmann constant)

$T_e = 273 + C$ (K)

C= 27 ℃

BW 是系統頻寬。根據式(1-2)的路徑損失模型，可以計算出基地台或手機接收功率，再將式(3)求得數值帶回式(4) 可求出接收器端的 SNR 數值。當載波頻率為 2G Hz，基地台之 Power 功率

相同皆使用 1W 時，在不同情境下，SNR 與距離差異如圖 3 所示。

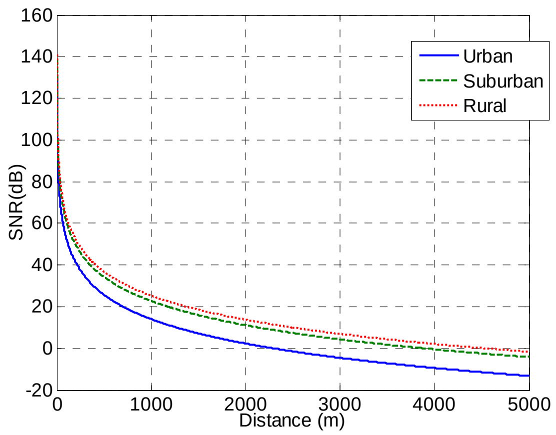

圖 3：SNR 與距離分析圖

1.4.使用者接收限制

本研究使用者接收限制，使用 Packet Error Rate(PER)為準則[3]，PER 之計算如式(5-6)，進而推出 Code Rate 1/3 之 PER 模型，如圖 4 所示，而本論文以 Packet Error Rate(PER)歸納出二種限制，10^{-3} 及 10^{-6}，來作 UE 接收端之參考。

(1)10^{-3}：SNR 為 3.3dB

(2)10^{-6}：SNR 為 5dB

$$p_{\gamma}(\gamma)=\frac{m^{m}\gamma^{m-1}}{\bar{\gamma}^{m}\Gamma(m)}\exp(-\frac{m\gamma}{\bar{\gamma}}) \quad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$\Gamma(m)=\int_{0}^{\infty}t^{m-1}e^{-t}dt \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

m：通道模型參數，當使用通道模型為 Rayleigh 時，m = 1

Packet size：封包大小為 1080 bit

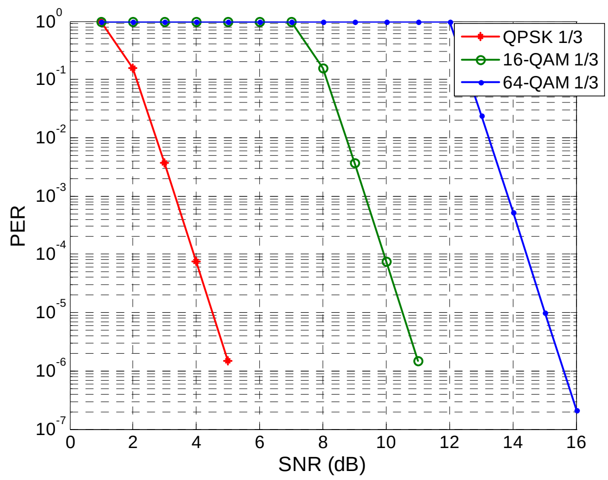

圖 4：PER 與 SNR 關係圖

1.5.接近現實下之基地台情境

在現實之情境下，使用者與基地台的關係並不只是在空曠空間，使用者亦有可能位於建築物裡，在此我們根據 3GPP Rel.9 所定義的室外到室內路徑損失模型[1](式 7-11)，而知道若位於建築物內時，路徑損失會過大而無法接收到資料，當建築物與基地台距離為 500m 時之路徑損失模型，如圖 5 所示，所以我們在使用 coordination 分析時，必當增加微小型基地台或訊號增益器來進行分析，而使整個模擬情境，更趨於現實。

其中 $\bar{\gamma}=\mathrm{E}\{\gamma\}$，$\Gamma(m)$:Gamma function

$$PL_{urban-micro}=40\log10(\mathrm{d})+7.8-18\log10(h_{BS})-18\log10(h_{UT})+2\log10(f_{c}) \quad \ldots..(7)$$

$$PL[dB]=PL_{b}+PL_{tw}+PL_{in} \quad \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$$PL_{b}=PL_{B1}(d_{out}+d_{in}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

$$P_{tw}=14+15(1-\cos(\theta))^{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

$$PL_{in}=0.5d_{in} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(11)$$

3m< d_{out}+d_{in} <100m, 0m<d_{in}<25m, h_{BS}=10m, h_{UT}=3n_{FL}+1.5m, n_{FL}=1, θ=45°

n_{FL}：室內穿越牆壁數

PL_{B1} :為 urban-micro 之路徑損失模型如式(7)

d_{out}：室外路徑之距離

d_{in}：室內路徑之距離,θ: 室外路徑與牆壁夾角

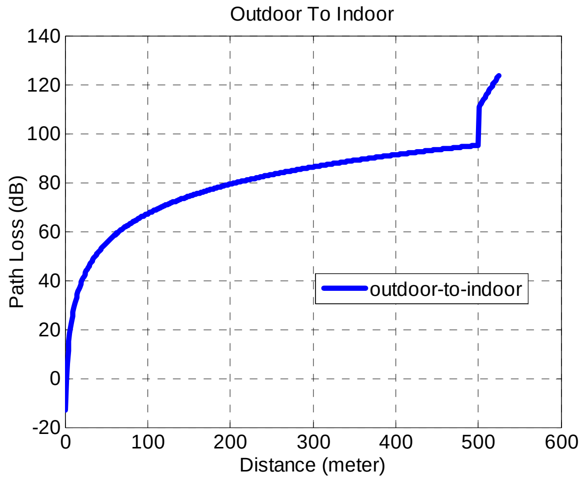

圖 5：The Near Real Scene Path Loss

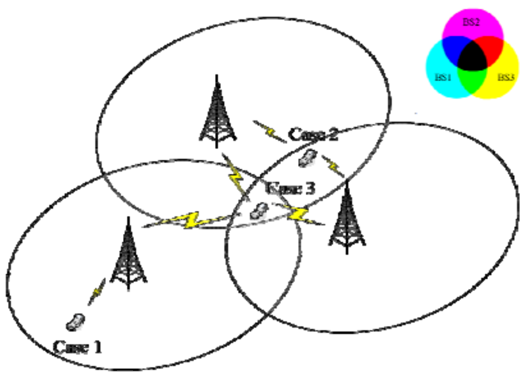

圖 6：使用者情境與顏色示意圖

2.基地台協調合作技術

2.1.使用者情境規劃

當使用者位於不同接收範圍，如圖 6 所示，歸納出 3 種情形，使用不同顏色來區分位於不同基地台之覆蓋範圍，以利於後面小節方便分析基地台頻寬使用情形。

Case 1:當使用者位於單一個基地台覆蓋範圍下，青藍：BS1、桃紅：BS2、黃：BS3

Case 2: 當使用者位於兩個基地台共同覆蓋範圍下，紅：BS2 & BS3、綠：BS1 & BS3、藍：BS1& BS2

Case 3: 當使用者位於三個基地台共同覆蓋範圍下，黑：BS1 & BS2 & BS3

2.2.基地台效能分析

本小節進行模擬 LTE 系統，於 coordination 下的差異比較與結果分析，模擬參數如下表 1 所示，分析是否使用 coordination 對系統效能有所影響，並分析 coordination 收斂下的結果。

表 1：LTE Parameter

Duplex Mode	FDD
Carrier Frequency	2G Hz
Bandwidth	10M Hz
Code Rate	1/3
AMC	QPSK、16-QAM、64QAM
BS Power	1W
BS antenna gain	17 dBi
UE antenna gain	0 dBi
UE Power	200 mW
BS Height	35 m
UE Height	1.5m
Path Loss	Macrocell urban
DL Traffic	128 Kbps
UL Traffic	64 Kbps

2.2.1.情境差異分析

本節將模擬使用者平均分佈在各個基地台覆蓋範圍下，分佈範圍如圖 7 中間紅色方框所示，在同樣的分佈情境，有無使用 Coordination，再參照 2.1 節從不同 BS 接收資料的顏色配對，圖 7 為有 Coordination，若使用者在複數基地台覆蓋範圍下，就可收到複數基地台來的資料，圖 8 為無 Coordination，使用者只接收到一個基地台的資料。

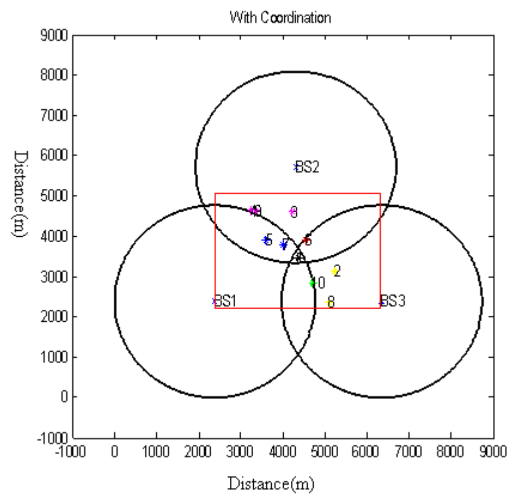

圖 7：使用 Coordination 下 UE 接收資料情形

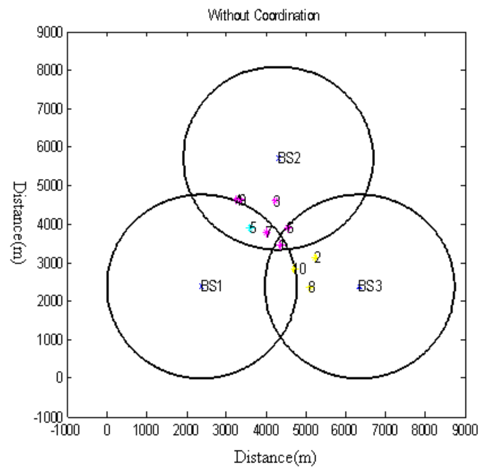

圖 8：未使用 Coordination 下 UE 接收資料情形

2.2.2.基地台頻寬使用分析

本小節將進行同樣情境，參照 2.2.1 小節的使用者分佈，有無使用 Coordination，對 BS 後端骨幹網路的影響，參照 2.1 節的顏色配對，圖 9 為有用 Coordination，圖 10 為無 Coordination，對於使用者同樣的分佈情形，當使用 Coordination 時，對 BS 後端骨幹網路的影響較大。圖 11 為有 Coordination DL/UL 頻寬使用情形。

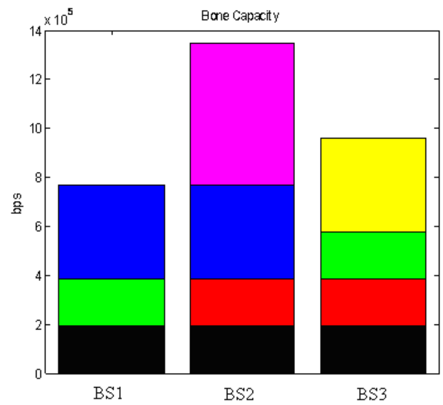

圖 9：With Coordination 頻寬佔用情形

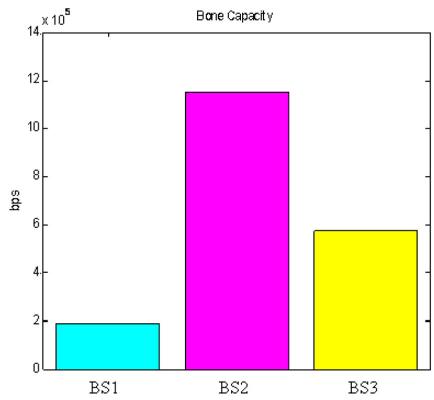

圖 10：Without Coordination 頻寬佔用情形

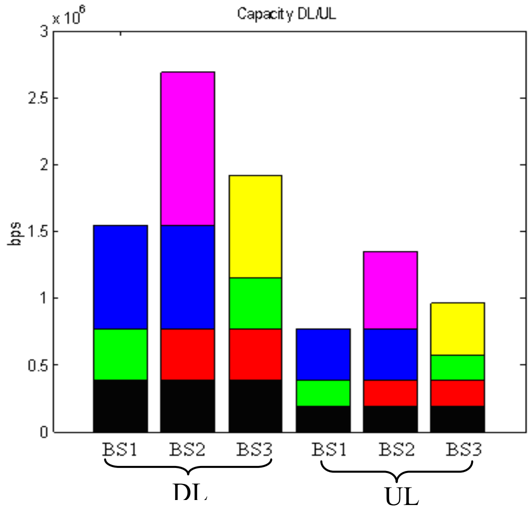

圖 11：With Coordination DL/UL 頻寬佔用情形

2.3.頻寬使用差異分析

本論文將分析當使用 Coordination 技術時，基地台後端網路頻寬因有所限制，所以我們將以使用者的多寡，來看頻寬佔用情形。下表 3 為使用者分別為 10、30、50、80、100、150、200 時，頻寬占用情形及使用者使用服務情形。下表 4 為使用者服務斷線情況，當使用 Coordination 技術時總服務的人數與未使用 Coordination 技術時總服務的人數比為 1.62：1。從使用者 DL 服務來看，如圖 12 所示，當使用者服務約少於 110 時，使用 Coordination，連線人數將會大於未使用 Coordination。從單一基地台後端網路來看時，當使用者約少於 120 人時，使用 Coordination ，針對後端網路的使用較有效率，如圖 13 所示，從三個為一組基地台的後端網路來看時，當使用者約少於 120 人時，使用 Coordination ，針對後端網路的使用較有效率，如圖 14 所示。

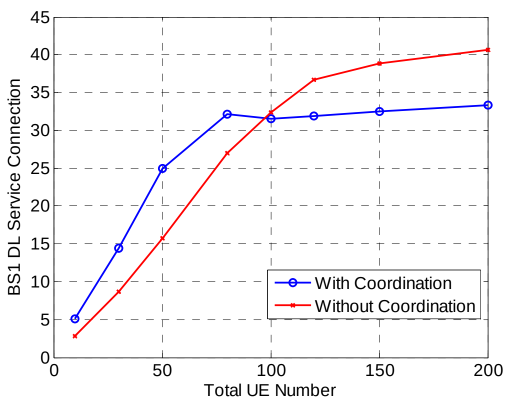

圖 12：單一個 BS 使用者 DL 服務情況

表 3：使用者服務與頻寬佔用情形

DL/UL成功連線人數　　總提出服務人數　　基地台後端網路流量

With Coordination																									
UE Number		10			30			50			80			100			120			150			200		
		DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service
BS1	Connect	5.1	5.1	5.1	14.4	14.4	14.4	24.9	24.9	24.9	32.1	38.3	38.3	31.5	48	48	31.9	59.2	59.2	32.5	63.7	66.3	33.3	64.3	98.1
BS2	Connect	4.8	4.8	4.8	16.9	16.9	16.9	26.5	26.6	26.6	34.1	41.5	41.5	33.9	54.1	54.1	33.1	60.9	60.9	32.4	64.7	70.2	33.2	67.1	105.9
BS3	Connect	5.1	5.1	5.1	15.6	15.6	15.6	24.4	24.4	24.4	31.3	38.4	38.4	31.7	46.5	46.5	30.6	56.9	56.9	31.9	62.8	68.2	33.4	64.2	97.2
BS1	Mbps	0.9792			2.7648			4.7808			6.56			7.104			7.872			8.2368			8.3776		
BS2	Mbps	0.9216			3.2448			5.0944			7.0208			7.8016			8.1344			8.288			8.544		
BS3	Mbps	0.9792			2.9952			4.6848			6.464			7.0336			7.5584			8.1024			8.384		
Without Coordination																									
UE Number		10			30			50			80			100			120			150			200		
		DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service
BS1	Connect	2.8	2.8	2.8	8.7	8.7	8.7	15.7	15.7	15.7	27	27	27	32.4	32.4	32.4	36.7	36.9	36.9	38.8	48.1	48.1	40.6	66.2	66.2
BS2	Connect	4.5	4.5	4.5	12.3	12.3	12.3	18.9	18.9	18.9	30.6	30.8	30.8	32.2	32.3	32.3	38.1	43.6	43.6	39.1	54.4	54.4	39.7	66.2	66.5
BS3	Connect	2.7	2.7	2.7	9	9	9	15.4	15.4	15.4	22.2	22.2	22.2	35.1	35.3	35.3	37.4	39.5	39.5	38.8	47.5	47.5	40.5	67.2	67.3
BS1	Mbps	0.5376			1.6704			3.0144			5.184			6.2208			7.0592			8.0448			9.4336		
BS2	Mbps	0.864			2.3616			3.6288			5.888			6.1888			7.6672			8.4864			9.3184		
BS3	Mbps	0.5184			1.728			2.9568			4.2624			6.752			7.3152			8.0064			9.4848		

表 4：使用者服務斷線率

With Coordination																	
	MS Number	10		30		50		80		100		120		150		200	
BS No.		DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL		
BS1		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.19%	0.00%	34.38%	0.00%	46.11%	0.00%	50.98%	3.92%	66.06%	34.45%
BS2		0.00%	0.00%	0.00%	0.00%	0.38%	0.00%	17.83%	0.00%	37.34%	0.00%	45.65%	0.00%	53.85%	7.83%	68.65%	36.64%
BS3		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	18.49%	0.00%	31.83%	0.00%	46.22%	0.00%	53.23%	7.92%	65.64%	33.95%
Without Coordination																	
	MS Number	10		30		50		80		100		120		150		200	
BS No.		DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL		
BS1		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.54%	0.00%	19.33%	0.00%	38.67%	0.00%
BS2		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.65%	0.00%	0.31%	0.00%	12.61%	0.00%	28.13%	0.00%	40.03%	0.45%
BS3		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.57%	0.00%	5.32%	0.00%	18.32%	0.00%	39.73%	0.15%

表 5：TDD 系統模擬參數

Duplex Mode	TDD
Carrier Frequency	2G Hz
Bandwidth	10M Hz
Code Rate	1/3
AMC	QPSK、16-QAM、64QAM
BS Power	1W
BS antenna gain	17 dBi
UE antenna gain	0 dBi
UE Power	200 mW
BS Height	35 m
UE Height	1.5 m
Path Loss	Macrocell urban

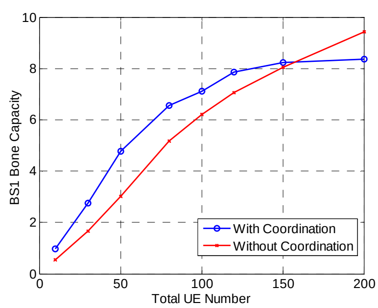

圖 13：單一個 BS 使用者頻寬使用情形

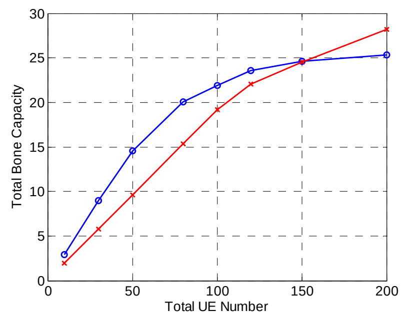

圖 14：三個 BS 使用者頻寬使用情形

2.4.TDD 下之頻寬使用分析

在次世代無線通訊系統下，亦有規劃 TDD 雙工模式，前面幾個小節以詳細介紹 Coordination 使用在 FDD 下之效能，此小節將來介紹 TDD 對系統頻寬效能的影響。次世代無線通訊系統下 TDD 之 DL 與 UL 有分成幾種 case，表 5 為 TDD 模擬系統參數，此小節選用其中 2 種模式作為比較，因本文使用者位置為隨機亂數產生，所以只單單模擬一次時可信度較差，所以從此節以下將進行模擬 10 次再取平均值。此小節中選用表 6 上下行排列組合 case1 與 case2，case 1 表示當 DL/UL 服務比例為 1:1，case 2 表示當 DL/UL 服務比例為 3:1。由此可以

發現不同的 TDD 模式，根據使用者服務之需求，將會影響不同的系統效能與使用者服務斷線率。

表 6：LTE 系統 TDD 訊框支援的上下行比例

上下行 排列	下行至上行 轉換點週期	子訊框編號									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

2.5.單一基地台負荷人數過大下頻寬使用分析

本小節將探討當單一基地台負荷人數過大時，像其中某個基地台涵蓋範圍下有活動或塞車時，還有是商圈人群聚集處，使用者人數將會大大超過其他基地台覆蓋之使用者人數，如圖 15 所示，前面小節已知使用 Coordination 會大大減少使用者人數服務，所以建議當基地台在此覆蓋下使用者人數遠多於其他基地台時，將不使用 Coordination 技術。將模擬當在 BS2 覆蓋下人數較多之情形，進行模擬 10 次取平均值，表 7 為使用者服務與頻寬佔用情形，表 8 為使用者服務斷線率，由於此小節模擬我們將知道 BS2 覆蓋下使用者人數較多時，不使用 Coordination 技術，將大大的降低 Fail Error Rate。

3、訊號增益器研析

在現實情境下，有些使用者位於室內時，接收不到室外基地台的訊號，於是有些大樓裡便會加裝 Repeater[16]，如圖 16 所示，使得室內使用者能透過 Repeater 來與室外基地台達到收訊目地。

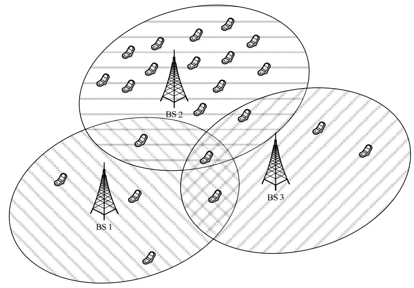

圖 15：單一基地台負荷人數過大情境示意圖

表 7：單一基地台負荷人數過大下之使用者服務與頻寬佔用情形

		With Coordination																							
	UE Numbe	10			30			50			80			100			120			150			200		
		DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service
BS1	Connect	4.5	4.5	4.5	11.0	11.0	11.0	20.4	20.4	20.4	27.5	32.5	32.5	28.0	38.9	38.9	29.3	48.6	48.6	28.9	56.2	56.2	30.0	57.6	74.1
BS2	Connect	7.1	7.1	7.1	22.1	22.1	22.1	28.4	36.2	36.2	29.9	57.4	57.4	29.1	58.4	71.1	30.3	58.1	85.1	29.1	58.2	103.1	30.5	58.6	140.2
BS3	Connect	4.2	4.2	4.2	10.9	10.9	10.9	18.2	18.2	18.2	25.7	28.0	28.0	27.0	33.2	33.2	28.6	40.4	40.4	28.0	53.3	53.3	29.3	55.6	69.5
BS1	Mbps	0.864			2.112			3.9168			5.6			6.0736			6.8608			7.296			7.5264		
BS2	Mbps	1.3632			4.2432			5.952			7.5008			7.4624			7.5968			7.4496			7.6544		
BS3	Mbps	0.8064			2.0928			3.4944			5.0816			5.5808			6.2464			6.9952			7.3088		
		BS2 Without Coordination 、BS1 BS3 With Coordination																							
	UE Numbe	10.0			30.0			50.0			80.0			100.0			120.0			150.0			200.0		
		DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service
BS1	Connect	4.2	4.2	4.2	12.6	12.6	12.6	18.2	18.2	18.2	28.0	31.9	31.9	29.6	39.5	39.5	29.5	51.4	51.4	29.6	56.5	56.5	29.0	57.5	72.3
BS2	Connect	3.7	3.7	3.7	9.9	9.9	9.9	18.4	18.4	18.4	30.8	30.8	30.8	36.9	36.9	36.9	36.2	40.2	40.2	38.6	55.2	55.2	38.1	73.2	75.3
BS3	Connect	3.7	3.7	3.7	10.8	10.8	10.8	17.7	17.7	17.7	24.1	25.3	25.3	27.3	34.4	34.4	27.7	42.3	42.3	27.8	51.5	51.5	28.0	56.0	69.2
BS1	Mbps	0.8064			2.4192			3.4944			5.6256			6.3168			7.0656			7.4048			7.392		
BS2	Mbps	0.7104			1.9008			3.5328			5.9136			7.0848			7.2064			8.4736			9.5616		
BS3	Mbps	0.7104			2.0736			3.3984			4.704			5.696			6.2528			6.8544			7.168		

表 8：單一基地台負荷人數過大下之使用者服務斷線率

	With Coordination															
	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL
UE Numbe	10		30		50		80		100		120		150		200	
BS1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	15.38%	0.00%	28.02%	0.00%	39.71%	0.00%	48.58%	0.00%	59.51%	22.27%
BS2	0.00%	0.00%	0.00%	0.00%	13.26%	0.00%	46.17%	0.00%	54.85%	15.05%	62.04%	30.20%	69.16%	38.02%	76.25%	53.92%
BS3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.21%	0.00%	18.67%	0.00%	29.21%	0.00%	47.47%	0.00%	57.84%	20.00%
	BS2 Without Coordination 、BS1 BS3 With Coordination															
	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL
UE Numbe	10		30		50		80		100		120		150		200	
BS1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	12.23%	0.00%	25.06%	0.00%	42.61%	0.00%	47.61%	0.00%	59.89%	20.47%
BS2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.95%	0.00%	30.07%	0.00%	49.40%	2.79%
BS3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.74%	0.00%	20.64%	0.00%	34.52%	0.00%	46.02%	0.00%	59.54%	19.08%

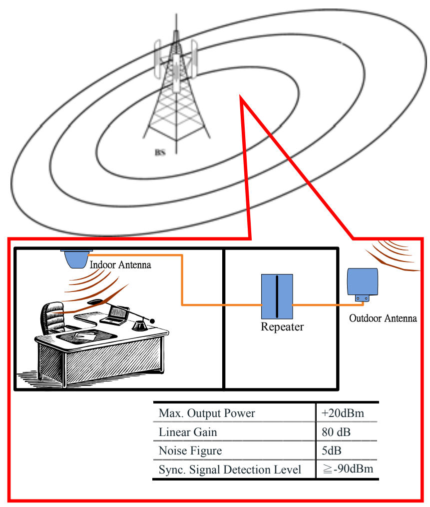

圖 16：Repeater 架設情境

基地台之天線與 Repeater 室外天線距離，會影響室內天線送出來的訊號品質，模擬當室外天線與基地台距離為 500m 與 1000m 時，室內天線所送出來的 SNR 值，如圖 17 所示

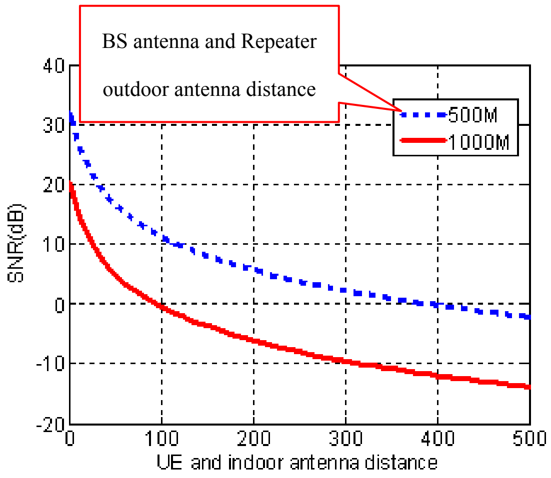

圖 17：室內天線送出來的 SNR 值

當使用者位處於室內環境下收不到外面基地台的訊號時，本情境增加 Repeater 來應變，如圖 18 所示，本小節將模擬當有 50 個房子下之情境進行模擬 10 次取平均值，使用者、房子與 Repeater 分佈範圍同圖 7 紅色方框，分析 coordination 下加入 Repeater 之使用者服務與頻寬佔用情形，如表 9 所示。由表 9 可以得知，當使用者人數約 170 人時，若加入 Repeater 時針對三個 BS 的頻寬總合，將有較高使用效率，如圖 19 所示。

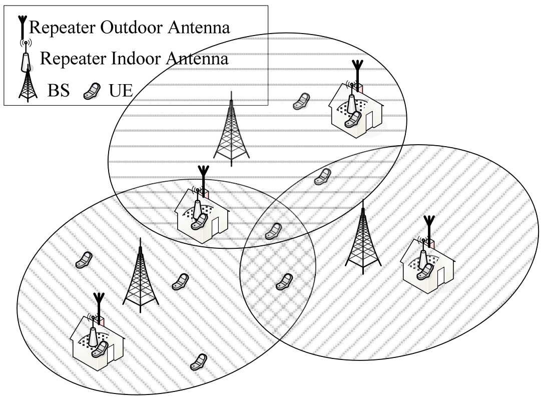

圖 18：Coordination 下 Repeater 架設情境

表 9：加入 Repeater 之使用者服務與頻寬佔用情形

With Repeater																	
	MS Number	10		30		50		80		100		120		150		200	
BS No.		DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL
BS 1	connect	3.6	3.6	15.5	15.5	25	25	31.7	40.6	32.6	47.9	32.4	56.5	31.9	63.8	31.6	63.5
BS 2	connect	5.5	5.5	16	16	25.2	25.9	33.6	43.9	33.4	52.3	33	59.9	34.2	66.4	32.2	64.9
BS 3	connect	4.9	4.9	14.9	14.9	24	24	31	36.6	32.5	47	32.4	59.2	31.9	63.9	30.7	61.8
BS 1	Mbps	0.6912		2.976		4.8		6.656		7.2384		7.7632		8.1664		8.1088	
BS 2	Mbps	1.056		3.072		4.8832		7.1104		7.6224		8.0576		8.6272		8.2752	
BS 3	Mbps	0.9408		2.8608		4.608		6.3104		7.168		7.936		8.1728		7.8848	
Total	Mbps	2.688		8.9088		14.2912		20.0768		22.0288		23.7568		24.9664		24.2688	
Without Repeater																	
	MS Number	10		30		50		80		100		120		150		200	
BS No.		DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL
BS 1	connect	5.1	5.1	12.8	12.8	22.6	22.6	31.6	36.7	33.4	42	31.7	53.6	32.3	62.4	32.9	65.6
BS 2	connect	4	4	13.7	13.7	23.7	23.7	32.1	36.7	32.9	47.4	32	55.9	33.2	63.9	34.1	67.1
BS 3	connect	3.9	3.9	12.4	12.4	19.4	19.4	29.9	32.8	32.5	39.2	32.2	50.3	31.6	59.2	32.3	63.7
Indoor	connect	1.3	1.3	3.9	3.9	6.1	6.1	8.5	8.5	12	12	12.5	12.5	18.3	18.3	21.4	21.4
BS 1	Mbps	0.9792		2.4576		4.3392		6.3936		6.9632		7.488		8.128		8.4096	
BS 2	Mbps	0.768		2.6304		4.5504		6.4576		7.2448		7.6736		8.3392		8.6592	
BS 3	Mbps	0.7488		2.3808		3.7248		5.9264		6.6688		7.3408		7.8336		8.2112	
Total	Mbps	2.496		7.4688		12.6144		18.7776		20.8768		22.5024		24.3008		25.28	

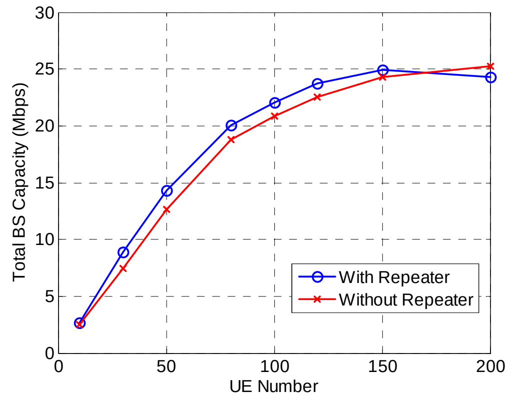

圖 19：加入 Repeater 下 Total BS Capacity

四、結論

當次世代行動通訊系統使用之頻寬越來越大時，因不同時間、環境，基地台範圍覆蓋下之使用者，有時密集，有時鬆散，當基地台頻寬使用效率變差，可使用基地台協調合作技術，來使頻寬有效利用，因而提高使用者之訊號強度。增加 Femto 可以增加 Coordination 整體所提供之效益，如圖 20 所示，增加的 Femto 數量越多時，所能提供整體之系統效能會越大。在未來可將 Coordination 技術使用在 Multicarrier，如圖 21 所示，在 Multicarrier 上可作一些 QoS(Quality of Service)，來降低使用 Coordination 時的 Fail Error Rate 及提升使用者服務人數，以及利用不同的 carrier 傳送不同的訊號，carrier 1 傳送 source data、carrier 2 傳送 HARQ 訊號等。

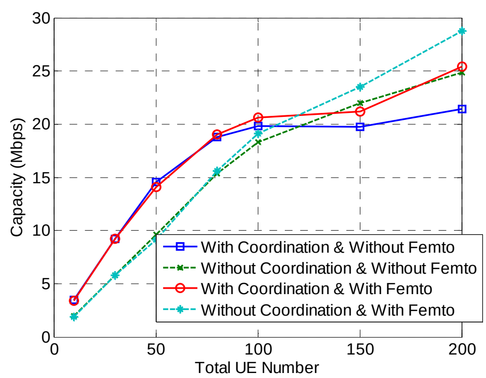

圖 20：Coordination 與 Femto 對系統效能關係圖

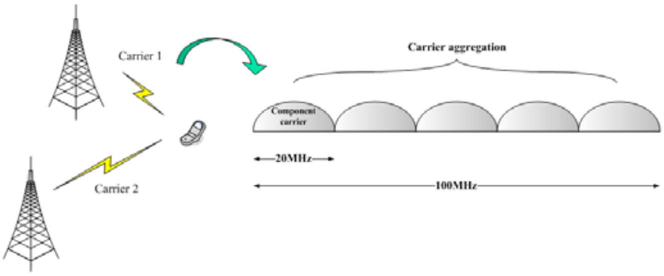

圖 21：Multicarrier 之 Coordination 架構

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國科會計畫補助專家學者出席國際會議報告書

□ 赴國外出差或研習
□ 赴大陸地區出差或研習
■ 出席國際學術會議
□ 國際合作研究計畫出國

計畫名稱		計畫編號	
會議/訪問時間地點	12-16 Sep 2011 Suzhou, China		
會議名稱	PIERS 2011 in Suzhou		
發表論文題目	1. New-type Low Power and Anti-interference Transmission Module		

一、此次參加的國際會議名稱為PIERS 2011 in Suzhou ，會議在大陸蘇州舉行，從9月12日到9月16日為期5天。在本次研討會中，本人共發表了一篇論文，並獲得與會專家學者許多寶貴之建議。同時也在其他場次，聽取前來的學者作相關論文發表，此外在會議期間，並和多位國際研究學者，針對相關主題進行討論，受益良多，並對自身的研究視野有諸多的提升。

二、對計畫之效益：Progress In Electromagnetics Research Symposium主要的議題為電磁相關及通訊技術領域的研討會議，與會人士對該會議之各項議題都提出許多問題，詢問報告人，有助於提升我們國家在研究方面的國際形象。同時以論文報告的方式參與國際研討會，有助於瞭解國際上目前在電磁相關領域的研究成果，藉此瞭解世界先進國家在此相關領域的研究趨勢及發展，對本計畫帶來更新的研究想法，以使本計畫能夠更臻完善。

三、心得：Progress In Electromagnetics Research Symposium會議為每年舉辦兩次的大型國際學術會議，參與研討會期間，體會到中國官方不僅著重於學術研究，並極力推廣主辦地點的文化與特色，在學術研究方面，此次議題為電磁相關等技術領域，Progress In Electromagnetics Research Symposium是相當重要的會議。本人參與此次研討會，並體會與國際人士的交流互動，以確能夠使自己的眼界更為寬廣，對於相關領域的研究亦可藉由分享彼此最新的研究成果，並更激發出新的想法及瞭解目前研究趨勢。

四、建議與結語：此次會議主題為電磁及通訊相關等技術領域的討論，主要在各種電磁及通訊問題方面的課題，參與其中的確可獲得不少新知，包括了天線設計、RF電路、無線網路相關技術、系統效能分析等各種新的技術、觀念或是應用，在來自世界各國的專家學者齊聚一堂的環境，分享彼此不同的觀念與想法，對未來研究提供不少助益。參與此次的國際性會議後，我深深覺得國科會補助出席國際會議對於研究人員以及國內研究風氣的提升，有非常大的幫助。

五、攜回資料PIERS 2011 in Suzhou會議論文集光碟片一片。

New-type Low Power and Anti-interference Transmission Module

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Abstract— A new modulation scheme for short range signal transmission is considered. The signal is modulated by sinusoidal waveforms and it is based on the majority of positive or negative waveforms in a symbol interval to determine which symbol, 1 or 0, is transmitted. The system performance implemented with this new modulation scheme is simulated and compares with the traditional BPSK modulation, it has the result that when the system is not synchronized and the transmitted signal suffers a delay greater than a threshold then the new design modulation scheme has a better performance than the traditional BPSK modulation and its allowable delay range is also larger than the BPSK format. With this modulation method we can simplify the receiver terminal hardware structure and to reduce the total system cost.

1. INTRODUCTION

As time evolves, many new wireless communications [1–3] have been developed and some wireline communications have been replaced by their equivalent wireless communications. Wireless communications have been applied in our surrounding environments either in the long range transmission or in the short distance communications; however in the wireless transmission it has serious interference problems [4] than that in the wireline transmissions. In this paper it is mainly considers the synchronization problem. In the communication system the goodness of synchronization at the receiving terminal determines the correctness of the demodulated signal and in order to generate correct demodulated signal it needs to know the correct starting position of the received symbols otherwise the system performance will be deteriorated. In this paper for short range transmission we develop a new modulation scheme and compare its performance, such as Bit Error Rate (BER), versus signal transmission delay time with the traditional applied BPSK modulation [5–8]. This paper is organized as follows. A new modulation format and its associated demodulation mechanism are introduced in Section 2. In Section 3 the system performance with the new modulation scheme is performed through MATLAB simulation. Finally a conclusion is drawn in Section 4.

2. CONSTRUCTION OF SIGNALS

As shown in Fig. 1 is the definition of the transmitted signals. For the symbol 0 it is the combination of one positive sinusoidal wave and two negative sinusoidal waves while for the symbol 1 it is the combination of two positive sinusoidal waves and one negative sinusoidal wave as shown in Equations (1) and (2) respectively with period of 3π.

$$S_1(t) = \left\{ \begin{array}{ll} \sin(t) & 0 \le t \le \frac{T}{3} \\ -\sin\left(t - \frac{T}{3}\right) & \frac{T}{3} \le t \le \frac{2T}{3} \\ -\sin\left(t - \frac{2T}{3}\right) & \frac{2T}{3} \le t \le T \end{array} \right\} \tag{1}$$

$$S_2(t) = \left\{ \begin{array}{ll} \sin(t) & 0 \le t \le \frac{T}{3} \\ \sin\left(t - \frac{T}{3}\right) & \frac{T}{3} \le t \le \frac{2T}{3} \\ -\sin\left(t - \frac{2T}{3}\right) & \frac{2T}{3} \le t \le T \end{array} \right\} \tag{2}$$

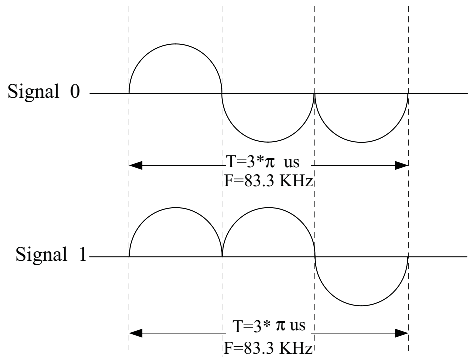

Figure 1: Construction of signals.

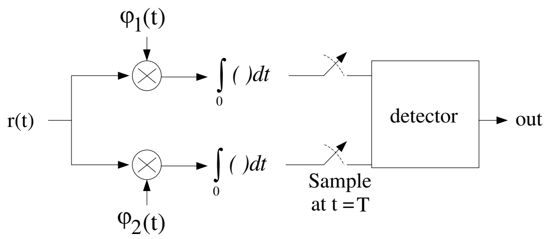

Figure 2: Functional block diagram for demodulation (method I).

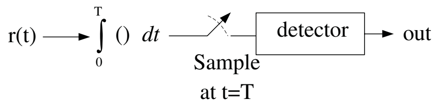

Figure 3: Functional block diagram for demodulation (method II).

In the new modulation design it has two demodulation methodologies and is described in the following: Method I: As shown in Fig. 2 is the functional block diagram for the traditional demodulation process. It first finds the basis $\varphi_1(t)$ and $\varphi_2(t)$ for the transmitted symbols, $S_1(t)$ and $S_2(t)$ respectively. The basis $\varphi_1(t)$ and $\varphi_2(t)$ are entered into the integrator to perform the integration over a symbol time, it uses one bit for one symbol in this paper. After integration, the signal is passed through Detector [9] to determine the symbol is one or zero as illustrated in Equations (3)–(6).

$$\varphi_1(t) = \frac{S_1(t)}{\sqrt{\varepsilon_1}} \tag{3}$$

$$C_{21} = \int_{-\infty}^{\infty} S_2(t)\varphi_1(t)dt \tag{4}$$

$$d_2(t) = S_2 - C_{21}\varphi_1(t) \tag{5}$$

$$\varphi_2(t) = \frac{d_2(t)}{\sqrt{\varepsilon_2}} \tag{6}$$

where ε_1 is the energy of symbol $S_1(t)$ and ε_2 is the energy for symbol $S_2(t)$.

Method II: The demodulation method is illustrated in Fig. 3. At the receiver terminal it bases on the number of positive and negatives waveforms it receives in one symbol interval to perform the demodulation process. From the definition of $S_1(t)$ and $S_2(t)$, if it has more positive waveforms then the transmitted signal will be $S_2(t)$, otherwise if it has more negative waveforms then the receiver will detect the signal is transmitted from $S_1(t)$.

3. SIMULATION RESULTS

3.1. Sampling Time

From Sampling theory we know that with a symbol interval of 3π, it will meet the Nyquist rate requirement when the sampling interval is less than $3\pi/2$. From this consideration if we select 10 samples per symbol interval it would be able to meet this Nyquist rate requirement and it would also be a proper choice from the considerations of BER performance and the hardware cost. From the simulation results as shown in Fig. 4, the system BER almost has the same performance when the number of samples per symbol interval is selected as either 10 or 128. As shown in the figure the result with 10 sample points is shown with solid line with circle while for 128 sample points it is represented by the solid line.

3.2. Simulation Results Without Delay

The system performance, BER vs. SNR, is compared between our proposed new modulation method and the traditional BPSK modulation with a period of 2π. The system performance is simulated in the channel with additive white Gaussian noise when the transmitted signal is maintained at the same power level [10, 11]. The simulation result is shown in Fig. 5 where the solid line with hollow circle represents the result from the implementation of Method I modulation, solid line with solid circle is the result from using Method II modulation and the solid line is the result from BPSK modulation. It also reveals from the figure that at the same SNR the BPSK has the lowest BER performance and under no delay assumption it has 2 dB degradation in Method I modulation comparing with the BPSK modulation while it is 13 dB worse in the Method II modulation. Since the new modulation we proposed is for short range transmission we will then consider when the SNR is fixed the delay effect on the system performance when the noise effect is ignored.

3.3. The Allowable Delay Range When the SNR Is Fixed

In this subsection we consider when SNR is fixed at certain level the relation between delay and system BER, it has simulation results as shown in Fig. 6 where we maintain the SNR at 16 dB and find how long the delay will be when the BER is so large that we could not successfully demodulate the transmitted signal. In the simulation the period for BPSK is selected as 2π while it is 3π for the new modulation method and its result is shown in Fig. 6. In the figure the dotted line represents the Method I modulation while Method II results is represented by the line with solid

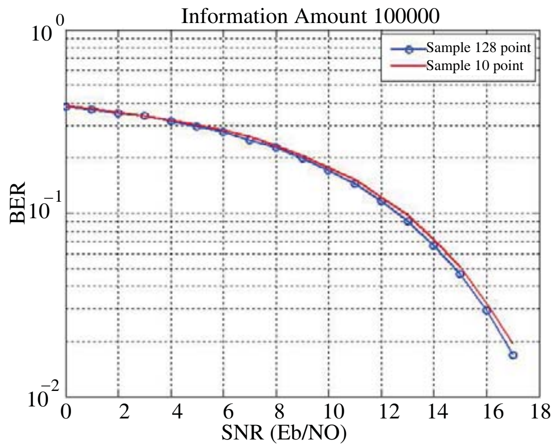

Figure 4: BER vs. SNR with sampling time as a parameter.

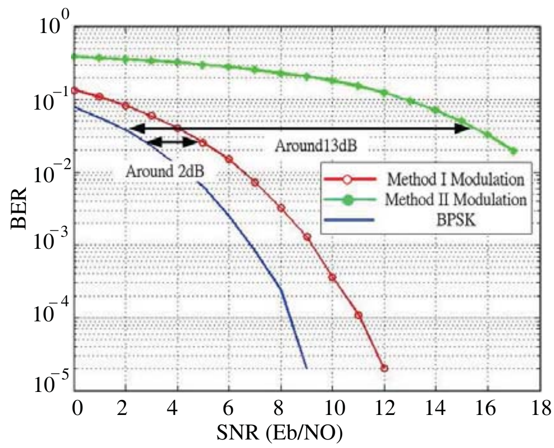

Figure 5: The system performance BER vs. SNR when the system does not introduce delay effect

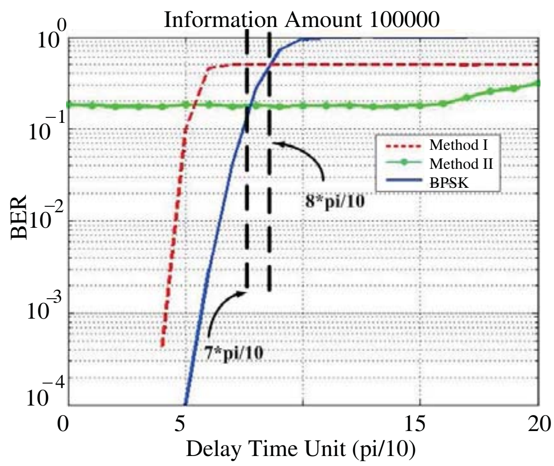

Figure 6: The allowable delay with new modulation methods.

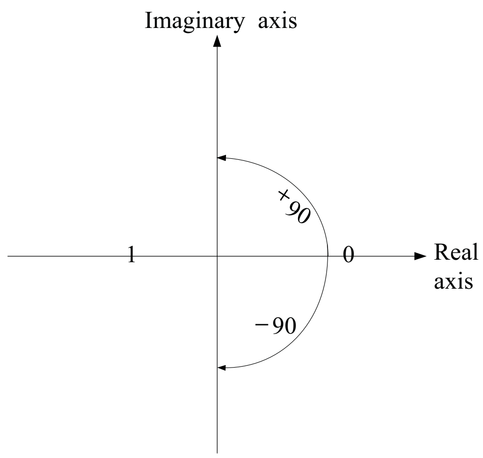

Figure 7: BPSK signal constellations.

circle and the result with BPSK modulation is represented by solid line; it appears that when the delay is around $7\pi/10$ and $8\pi/10$ for Method I and Method II respectively, the BPSK will have better performance than both new modulation methods while when the delay is greater than $7\pi/10$ and $8\pi/10$ respectively for Method I and Method II modulations the new modulation method has better performance than the traditional BPK modulation.

In the traditional BPSK demodulation when the phase shift is greater than 90 degrees it will incur demodulation error; as shown in Fig. 7 when the received signal is located in the right half of the real axis it is demodulated as a '0' symbol while it is demodulated as a '1' symbol when the received signal is located in the left real axis. Therefore when the signal suffers more than $\pm 90°$ phase shift in the BPSK modulation it will generate a detected error. However with our new proposed modulation method it makes decision from the waveform point of view when the received waveforms have more positive waveforms then it is detected as the symbol '1' while if it has more negative waveforms it is declared as symbol '0' transmitted and therefore the effect of the phase shift or the delay on the system performance will not be so great than that in the traditional BPSK modulation.

4. CONCLUSION

A new modulation scheme and receiver design was introduced in this paper. The signal was modulated by sinusoidal waveforms and at the receiver terminal it was based on the majority of positive or negative waveforms in a symbol interval to determine which symbol, 1 or 0, was transmitted. Although the system performance vs. noise of our proposed modulation scheme was not as good as the traditional BPSK modulation but since our proposed modulation system was for short range transmission the noise effect on the system was not the main issue in our consideration. On the other hand we used the detection principle based on the majority number of positive or negative waveforms to find the transmitted symbol and we simulated the new system performance and compared its system performance with the traditional BPSK modulation when the system is not synchronized; when the transmitted signal has a delay greater than a threshold then the new design had a better performance than the traditional BPSK modulation and its allowable delay range is also larger than the BPSK format. With this modulation method we can simplify the hardware structure of the receiver terminal and also to reduce the total system cost.

ACKNOWLEDGMENT

The authors would like to express their sincere thanks to I.-Yu, Kuo. This study is partially support from the National Science Council, R.O.C. under contracts NSC99-2219-E-009–014, NSC97-2221-E-032–027-MY3.

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Subgridding Scheme for FDTD in Cylindrical Coordinates

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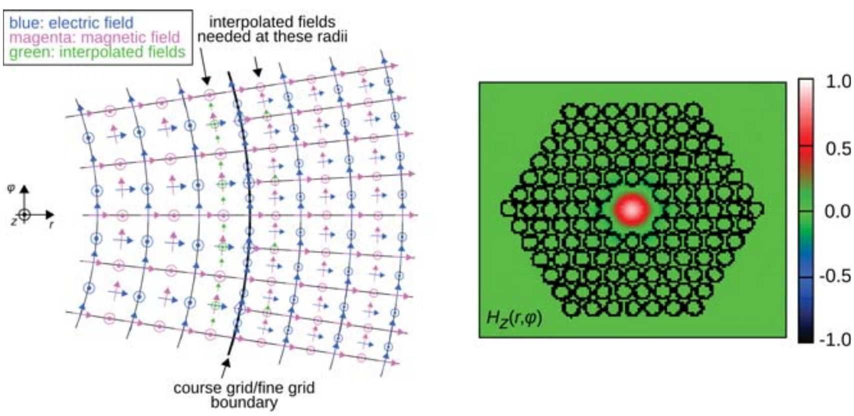
Abstract— A grid resolution compensation scheme based on subgridding is proposed and evaluated for improving the performance of the finite-difference time-domain method implemented in cylindrical coordinates. The scheme introduces subgrids into the domain with smaller azimuthal grid spacings. This work investigates interpolation methods used for estimating unknown but required field values at the interface between grids with different azimuthal grid spacings. It is found that cubic, cubic spline and trigonometric interpolation cause less than 1% error in estimating the frequencies of the propagating modes of a microstructured optical fiber. Multiple subgrids have the potential for significant domain size reduction and minimum time step enlargement.

1. INTRODUCTION

Accurate analysis of the electromagnetics of dielectric structures with complicated wavelength-scale geometry variation most often requires a numerical approach. This work presents a study of subgridding methods for improving the efficiency of the finite-difference time-domain (FDTD) method implemented in cylindrical coordinates. FDTD in cylindrical coordinates is attractive for the analysis of geometries with continuous [1, 2] or discrete [3] azimuthal invariance, and the interest of this work is structures with discrete azimuthal invariance. Examples of structures possessing this symmetry include point defect two-dimensional photonic crystal cavities [4, 5], microgear resonators [6] and microstructured optical fibers [7] (MOFs).

The numerical methods described herein will be applied to the analysis of microstructured optical fibers. MOFs differ from standard optical fibers by the inclusion of micrometer scale geometric features in the fiber cross section that run the entire length of the fiber [8]. Figure 1(a) illustrates the magnetic field associated with a MOF made up of a triangular hole array with 7 holes missing from the center. The field is confined to the central defect region due to both a larger effective index there as well as Bragg reflection from the periodic dielectric distribution surrounding the defect region. These confinement mechanisms along with the highly nonuniform dielectric distribution make the modal properties of MOFs significantly more complicated than the modal properties of standard optical fibers.

However, MOFs are similar to standard fibers in their geometric uniformity along the propagation direction. Because these fiber geometries are uniform along the longitudinal direction, the field behavior along this direction may be characterized by a propagation factor $\exp(j\beta z)$. Derivatives with respect to z can be evaluated analytically which reduces the computational domain from three to two dimensions while still maintaining a fully vectorial solution to Maxwell's equations. This approach has been called the "compact" version of FDTD [9–11] and is applicable to waveguide geometries continuous along the propagation direction [1, 12, 13].



(a) (b)

Figure 1: (a) Course grid/fine grid boundary. (b) Field distribution in microstructured optical fiber.

國科會補助計畫衍生研發成果推廣資料表

日期:2012/10/24

國科會補助計畫	計畫名稱: 高速移動之多天線與多頻道無線通訊之通道模型與干擾控制之研究
	計畫主持人: 詹益光
	計畫編號: 100-2221-E-032-031-　　　　學門領域: 通訊

無研發成果推廣資料

100 年度專題研究計畫研究成果彙整表

<table>
<tr><td colspan="3">計畫主持人：詹益光</td><td colspan="5">計畫編號：100-2221-E-032-031-</td></tr>
<tr><td colspan="8">計畫名稱：高速移動之多天線與多頻道無線通訊之通道模型與干擾控制之研究</td></tr>
<tr><td colspan="3" rowspan="2">成果項目</td><td colspan="3">量化</td><td rowspan="2">單位</td><td rowspan="2">備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）</td></tr>
<tr><td>實際已達成數（被接受或已發表）</td><td>預期總達成數(含實際已達成數)</td><td>本計畫實際貢獻百分比</td></tr>
<tr><td rowspan="12">國內</td><td rowspan="4">論文著作</td><td>期刊論文</td><td>0</td><td>0</td><td>100%</td><td rowspan="3">篇</td><td></td></tr>
<tr><td>研究報告/技術報告</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>研討會論文</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>專書</td><td>0</td><td>0</td><td>100%</td><td></td><td></td></tr>
<tr><td rowspan="2">專利</td><td>申請中件數</td><td>0</td><td>0</td><td>100%</td><td rowspan="2">件</td><td></td></tr>
<tr><td>已獲得件數</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td rowspan="2">技術移轉</td><td>件數</td><td>0</td><td>0</td><td>100%</td><td>件</td><td></td></tr>
<tr><td>權利金</td><td>0</td><td>0</td><td>100%</td><td>千元</td><td></td></tr>
<tr><td rowspan="4">參與計畫人力（本國籍）</td><td>碩士生</td><td>0</td><td>0</td><td>100%</td><td rowspan="4">人次</td><td></td></tr>
<tr><td>博士生</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>博士後研究員</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>專任助理</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td rowspan="12">國外</td><td rowspan="4">論文著作</td><td>期刊論文</td><td>2</td><td>0</td><td>100%</td><td rowspan="3">篇</td><td></td></tr>
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<tr><td>專書</td><td>0</td><td>0</td><td>100%</td><td>章/本</td><td></td></tr>
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<tr><td>權利金</td><td>0</td><td>0</td><td>100%</td><td>千元</td><td></td></tr>
<tr><td rowspan="4">參與計畫人力（外國籍）</td><td>碩士生</td><td>3</td><td>2</td><td>100%</td><td rowspan="4">人次</td><td></td></tr>
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<tr><td>專任助理</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
</table>

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	本計畫總共產出國際期刊論文共兩篇、會議論文共一篇，分別如下所述: 期刊 1.Performance Analysis with Coordination Among Base Stations for Next Generation Communication System(PIERS B) 2.The Measurement and Analysis of WiMAX Base Station Signal Coverage(PIERS C) 研討會 1.The Design of A Low Power Wireless Transmission System，該三篇論文對於新世代行動通訊技術之發展與研究有相當的貢獻。

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

　□實驗失敗

　□因故實驗中斷

　□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

本計畫總共產出國際期刊論文共兩篇、會議論文共一篇，分別如下所述：期刊 1.Performance Analysis with Coordination Among Base Stations for Next Generation Communication System(PIERS B) 2.The Measurement and Analysis of WiMAX Base Station Signal Coverage(PIERS C) 研討會 1.The Design of A Low Power Wireless Transmission System，該三篇論文對於新世代行動通訊技術之發展與研究有相當的貢獻。