

無人機產業 第五篇分享文:

無線高速移動換手連線(Handover)的重疊距離範圍評估

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最近經常有人問，你們的無線高速移動傳輸，可以應付多快的飛速/車速連線與切換速度及延時？

其實，無線傳輸速度是接近光速，相當於 1 秒無線傳輸，可以繞地球 7 圈半，所以，即使是從台灣頭傳輸到台灣尾的無線傳輸速度，都在 ns 級以上（0.0000001 秒）。

因此，只需討論處裡無線發射的電路硬體元件效能與處理過程的延時及軟硬體切換不同頻率的無線模組連線延時，才是研發技術的重點!!

分享文的目的之一，就是落實慢慢讓產業人士與同好網友，有機會從分享文中看到不同的知識或應用，看懂多少都沒關係，學習是慢慢累積的；要改善無人機的產業生態，能做多少，就做多少，我有盡力就好，至少做出動作嘗試了，就不會後悔!! 哈哈，有年紀的人，常常有這種情愫!!

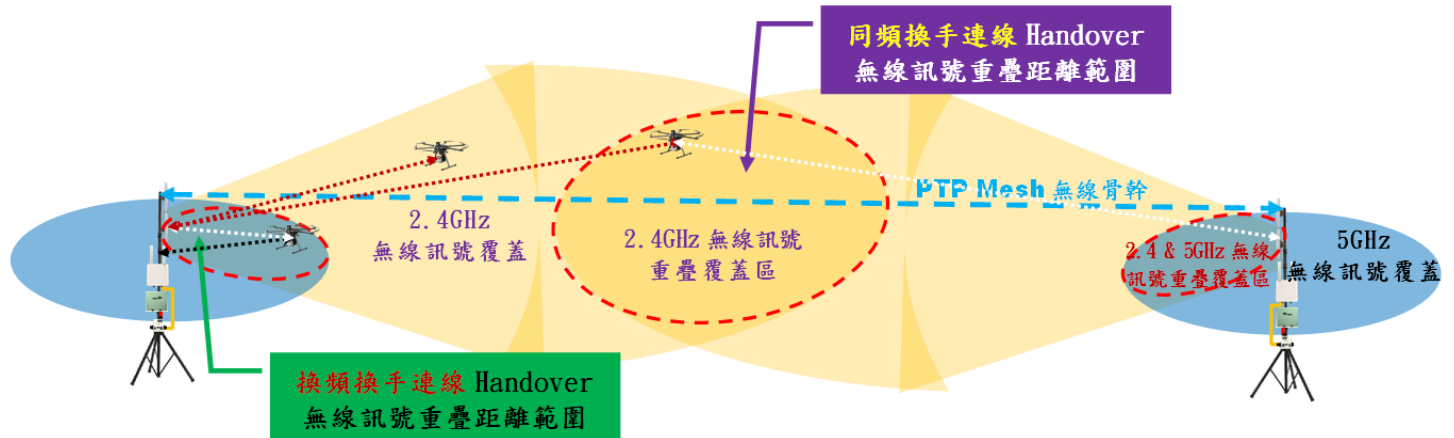
不多言，今天就來分享兩部分：

1. 無線高速移動換手連線的重疊距離範圍計算
2. 無線高速移動的『相同頻率的跳頻切換』與『不同頻率的換頻切換』測試驗證說明

有點技術理解難度，希望我的簡化說明，對產業內的人有所助益!!

Ps: 每家無線軟體研發廠商，都會有自己的無線連線切換技術，包括中華電信的 4G/5G 電信或其他無線頻率的廠商，當然也包括軍用的無線傳輸，技術創意才是彼此之間的差異所在，若有更多時間與實績環境驗證，成效會更快!!

無線高速移動換手連線(Handover)的重疊距離範圍評估



■ 車速/飛速 300Km/hr

300Km = 300,000m

1hr = 60min = 3,600sec = 3,600,000ms

1ms → 300,000m / 3,600,000ms = 0.083m

>>無線高速移動 300Km/hr 的換手連線，可控制在 35ms 完成

35ms handover → 2.9m / 50ms handover → 4.15m / 100ms handover → 8.3m

◆ 提供無線高速移動軟體，可有 100 次換手連線嘗試機會!!

訊號重疊區距離範圍 = 2.9m * 100 次 = 290m

■ 車速/飛速 200Km/hr

200Km = 200,000m 1hr = 60min = 3,600sec = 3,600,000ms 1ms → 200,000m / 3,600,000ms = 0.055m

>>無線高速移動 200Km/hr 的換手連線，可控制在 30ms 完成

30ms handover → 1.6m / 50ms handover → 2.75m / 100ms handover → 5.5m

◆ 提供無線高速移動軟體，可有 100 次換手連線嘗試機會!!

訊號重疊區距離範圍 = 1.6m * 100 次 = 160m

■ 車速/飛速 100Km/hr

100Km = 100,000m 1hr = 60min = 3,600sec = 3,600,000ms 1ms → 100,000m / 3,600,000ms = 0.027m

>>無線高速移動 100Km/hr 的換手連線，可控制在 25ms 完成

25ms handover → 0.67m / 50ms handover → 1.35m / 100ms handover → 2.7m

◆ 提供無線高速移動軟體，可有 100 次換手連線嘗試機會!!

訊號重疊區距離範圍 = 0.67m * 100 次 = 67m

■ 車速/飛速 50Km/hr

50Km = 50,000m 1hr = 60min = 3,600sec = 3,600,000ms 1ms → 50,000m / 3,600,000ms = 0.013m

>>無線高速移動 50Km/hr 的換手連線，可控制在 25ms 完成

25ms handover → 0.32m / 50ms handover → 0.65m / 100ms handover → 1.3m

◆ 提供無線高速移動軟體，可有 100 次換手連線嘗試機會!!

訊號重疊區距離範圍 = 0.32m * 100 次 = 32m

總結:特別設計的無線高速移動換手連線(Handover)技術，若要控制在 30ms 以內完成，雖然是艱難目標，但只要研發者有創意與累積實戰經驗修正，還是可達成不可能的任務!!

■ 高速移動重疊無線訊號覆蓋--換手連線測試記錄檔解說

註 0: 34:4f:3f:70:00:b4 (RSU 端的 Ethernet Port MAC ID)

註 1: OBU: R1-2.4GHz/ R2-5GHz ; RSU: R1-2.4GHz/ R2-5GHz/ R3-5GHz

註 2: (R2-R3) : OBU-R2 連線到 RSU-R3 (判斷切換到哪個無線訊號覆蓋依據)

註 3: 65, 65, : OBU-65 RSU-65 連線 Cost 成本 (判斷是否切換依據; 斷線 Cost 成本 1000~∞)

註 4: -29, -31, : OBU: -29dBm, RSU: -31dBm RSSI 訊號強度(值)

註 5: 866666, 866666 : OBU-866666 傳輸率, RSU-866666 傳輸率

註 6: 9, 24 : OBU-9bit, RSU-24bit 傳輸流量

>>> 採取拆除 RSU 的外接天線方式, 引導 OBU 積極切換不同的 RSU 介面!!

,2024/6/5 上午 8:58:10, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -29, -31, 866666, 866666, 9, 24

,2024/6/5 上午 8:58:11, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -29, -31, 866666, 866666, 11, 7

,2024/6/5 上午 8:58:12, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -29, -31, 866666, 866666, 11, 7

,2024/6/5 上午 8:58:14, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -29, -31, 866666, 866666, 7, 3

,2024/6/5 上午 8:58:15, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -29, -34, 866666, 866666, 7, 3

,2024/6/5 上午 8:58:16, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -38, -37, 866666, 780000, 9, 23

,2024/6/5 上午 8:58:17, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -30, -35, 780000, 780000, 10, 5

,2024/6/5 上午 8:58:19, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -38, -40, 780000, 650000, 1, 20

,2024/6/5 上午 8:58:20, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -43, -38, 780000, 650000, 1, 20

,2024/6/5 上午 8:58:21, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -39, -42, 866666, 780000, 1, 1

,2024/6/5 上午 8:58:22, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -41, -45, 650000, 433333, 6, 21

,2024/6/5 上午 8:58:24, 34:4f:3f:70:00:b4(R2-R3), 65, 67, -42, -45, 650000, 433333, 5, 21

,2024/6/5 上午 8:58:25, ~~~~~ switch ~~~~~ 第 1 次由 5GHz 換頻方式切換到 2.4GHz 『不同頻切頻』

,2024/6/5 上午 8:58:25, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -34, -26, 300000, 300000, 1, 1

,2024/6/5 上午 8:58:26, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -32, -25, 300000, 300000, 6, 21

,2024/6/5 上午 8:58:28, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -34, -25, 300000, 300000, 5, 1

,2024/6/5 上午 8:58:29, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -34, -25, 300000, 300000, 2, 21

,2024/6/5 上午 8:58:30, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -34, -24, 300000, 300000, 11, 24

,2024/6/5 上午 8:58:31, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -34, -24, 300000, 300000, 5, 1

,2024/6/5 上午 8:58:33, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -33, -24, 300000, 300000, 2, 21

,2024/6/5 上午 8:58:34, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -34, -29, 300000, 270000, 7, 22

,2024/6/5 上午 8:58:35, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -35, -25, 65000, 300000, 6, 3

,2024/6/5 上午 8:58:37, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -34, -25, 300000, 300000, 6, 21

,2024/6/5 上午 8:58:38, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -38, -24, 300000, 270000, 5, 1

,2024/6/5 上午 8:58:39, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -32, -25, 300000, 300000, 7, 23

,2024/6/5 上午 8:58:40, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -33, -25, 57777, 300000, 6, 21

,2024/6/5 上午 8:58:42, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -39, -25, 300000, 300000, 5, 1

,2024/6/5 上午 8:58:43, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -34, -28, 300000, 300000, 7, 23

,2024/6/5 上午 8:58:44, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -41, -29, 300000, 300000, 7, 22

,2024/6/5 上午 8:58:45, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -39, -30, 300000, 300000, 1, 1

,2024/6/5 上午 8:58:47, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -40, -31, 300000, 300000, 12, 24
,2024/6/5 上午 8:58:48, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -40, -34, 300000, 300000, 5, 1
,2024/6/5 上午 8:58:49, 34:4f:3f:70:00:b4(R1-R1), 58, 68, -44, -35, 150000, 150000, 2, 21
,2024/6/5 上午 8:58:51, 34:4f:3f:70:00:b4(R1-R1), 61, 68, -45, -41, 150000, 150000, 11, 23
,2024/6/5 上午 8:58:52, 34:4f:3f:70:00:b4(R1-R1), 67, 70, -53, -51, 150000, 150000, 5, 1
,2024/6/5 上午 8:58:53, ~~~~~ switch ~~~~~ 第 2 次由 2.4GHz 換頻方式切換到 5GHz 『不同頻切頻』
,2024/6/5 上午 8:58:53, 34:4f:3f:70:00:b4(R2-R2), 69, 71, -42, -44, 650000, 433333, 0, 0
,2024/6/5 上午 8:58:54, 34:4f:3f:70:00:b4(R2-R2), 69, 71, -40, -42, 650000, 433333, 6, 21
,2024/6/5 上午 8:58:56, 34:4f:3f:70:00:b4(R2-R2), 69, 71, -43, -45, 585110, 433333, 6, 3
,2024/6/5 上午 8:58:57, 34:4f:3f:70:00:b4(R2-R2), 69, 71, -41, -44, 585110, 433333, 6, 21
,2024/6/5 上午 8:58:58, 34:4f:3f:70:00:b4(R2-R2), 69, 71, -43, -42, 585110, 433333, 5, 1
,2024/6/5 上午 8:58:59, 34:4f:3f:70:00:b4(R2-R2), 69, 71, -43, -42, 585110, 433333, 7, 23
,2024/6/5 上午 8:59:01, 34:4f:3f:70:00:b4(R2-R2), 69, 71, -43, -42, 650000, 433333, 6, 21
,2024/6/5 上午 8:59:02, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -42, -41, 780000, 433333, 5, 1
,2024/6/5 上午 8:59:03, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -42, -43, 585110, 433333, 7, 23
,2024/6/5 上午 8:59:05, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -42, -42, 585110, 433333, 7, 22
,2024/6/5 上午 8:59:06, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -42, -42, 650000, 433333, 1, 1
,2024/6/5 上午 8:59:07, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -42, -42, 650000, 433333, 12, 24
,2024/6/5 上午 8:59:08, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -42, -42, 650000, 433333, 5, 21
,2024/6/5 上午 8:59:10, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -42, -42, 650000, 433333, 2, 1
,2024/6/5 上午 8:59:11, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -42, -42, 650000, 433333, 12, 24
,2024/6/5 上午 8:59:12, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -42, -42, 650000, 433333, 5, 1
,2024/6/5 上午 8:59:14, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -42, -42, 650000, 433333, 2, 20
,2024/6/5 上午 8:59:15, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -45, -41, 650000, 433333, 11, 23
,2024/6/5 上午 8:59:16, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -41, -45, 650000, 433333, 6, 2
,2024/6/5 上午 8:59:17, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -44, -48, 650000, 433333, 6, 21
,2024/6/5 上午 8:59:19, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -43, -44, 780000, 433333, 6, 21
,2024/6/5 上午 8:59:20, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -44, -40, 650000, 520000, 6, 3
,2024/6/5 上午 8:59:21, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -44, -40, 650000, 433333, 6, 21
,2024/6/5 上午 8:59:22, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -44, -40, 650000, 433333, 5, 1
,2024/6/5 上午 8:59:24, 34:4f:3f:70:00:b4(R2-R2), 69, 70, -44, -40, 650000, 433333, 7, 23
,2024/6/5 上午 8:59:25, ~~~~~ switch ~~~~~ 第 3 次由 5GHz 切換到相同 5GHz 的 『同頻切頻方式』
,2024/6/5 上午 8:59:25, 34:4f:3f:70:00:b4(R2-R3), 68, 69, -39, -43, 292555, 325000, 4, 1
,2024/6/5 上午 8:59:26, 34:4f:3f:70:00:b4(R2-R3), 68, 69, -42, -42, 292555, 433333, 4, 1
,2024/6/5 上午 8:59:28, 34:4f:3f:70:00:b4(R2-R3), 68, 69, -41, -43, 325000, 433333, 7, 23
,2024/6/5 上午 8:59:29, 34:4f:3f:70:00:b4(R2-R3), 68, 69, -41, -42, 390000, 433333, 6, 21
,2024/6/5 上午 8:59:30, 34:4f:3f:70:00:b4(R2-R3), 68, 69, -39, -40, 390000, 585110, 1, 1
,2024/6/5 上午 8:59:31, 34:4f:3f:70:00:b4(R2-R3), 68, 69, -40, -40, 433333, 520000, 5, 1
,2024/6/5 上午 8:59:33, 34:4f:3f:70:00:b4(R2-R3), 68, 69, -36, -38, 433333, 520000, 2, 21
,2024/6/5 上午 8:59:34, 34:4f:3f:70:00:b4(R2-R3), 68, 68, -39, -40, 520000, 585110, 12, 24
,2024/6/5 上午 8:59:35, 34:4f:3f:70:00:b4(R2-R3), 68, 68, -39, -41, 585110, 585110, 12, 24

,2024/6/5 上午 8:59:36, 34:4f:3f:70:00:b4(R2-R3), 68, 68, -39, -40, 585110, 650000, 2, 21
,2024/6/5 上午 8:59:38, 34:4f:3f:70:00:b4(R2-R3), 68, 68, -37, -37, 650000, 780000, 2, 21
,2024/6/5 上午 8:59:39, 34:4f:3f:70:00:b4(R2-R3), 66, 66, -38, -40, 650000, 866666, 6, 3
,2024/6/5 上午 8:59:40, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -35, -36, 866666, 780000, 6, 21
,2024/6/5 上午 8:59:42, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -31, -35, 866666, 780000, 6, 2
,2024/6/5 上午 8:59:43, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -28, -29, 866666, 780000, 6, 2
,2024/6/5 上午 8:59:44, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -26, -27, 866666, 866666, 6, 21
,2024/6/5 上午 8:59:45, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -28, -29, 866666, 866666, 5, 1
,2024/6/5 上午 8:59:47, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -29, 866666, 866666, 8, 24
,2024/6/5 上午 8:59:48, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -28, -30, 866666, 866666, 6, 21
,2024/6/5 上午 8:59:49, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -26, -28, 866666, 866666, 1, 1
,2024/6/5 上午 8:59:51, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -26, -29, 866666, 866666, 12, 24
,2024/6/5 上午 8:59:52, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -26, -29, 866666, 866666, 6, 21
,2024/6/5 上午 8:59:53, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -26, -28, 866666, 866666, 2, 1
,2024/6/5 上午 8:59:54, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -31, -31, 866666, 866666, 12, 24
,2024/6/5 上午 8:59:56, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -26, -28, 866666, 650000, 5, 1
,2024/6/5 上午 8:59:57, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -26, -28, 866666, 780000, 2, 21
,2024/6/5 上午 8:59:58, ~~~~~ switch ~~~~~第 4 次由 5GHz 切換到相同 5GHz 的『同頻切頻方式』
,2024/6/5 上午 8:59:58, 34:4f:3f:70:00:b4(R2-R2), 70, 73, -46, -47, 866666, 433333, 11, 22
,2024/6/5 上午 8:59:59, 34:4f:3f:70:00:b4(R2-R2), 70, 73, -44, -47, 780000, 433333, 6, 2
,2024/6/5 上午 9:00:01, 34:4f:3f:70:00:b4(R2-R2), 70, 73, -48, -49, 780000, 433333, 1, 20
,2024/6/5 上午 9:00:02, 34:4f:3f:70:00:b4(R2-R2), 71, 72, -48, -44, 650000, 433333, 6, 22
,2024/6/5 上午 9:00:03, 34:4f:3f:70:00:b4(R2-R2), 73, 72, -52, -48, 650000, 433333, 6, 3
,2024/6/5 上午 9:00:05, 34:4f:3f:70:00:b4(R2-R2), 73, 72, -48, -46, 780000, 433333, 6, 21
,2024/6/5 上午 9:00:06, 34:4f:3f:70:00:b4(R2-R2), 73, 72, -48, -48, 780000, 433333, 5, 1
,2024/6/5 上午 9:00:07, 34:4f:3f:70:00:b4(R2-R2), 73, 72, -48, -48, 650000, 433333, 8, 24
,2024/6/5 上午 9:00:08, 34:4f:3f:70:00:b4(R2-R2), 73, 72, -47, -48, 780000, 433333, 6, 21
,2024/6/5 上午 9:00:10, ~~~~~ switch ~~~~~第 5 次由 5GHz 切換到相同 5GHz 的『同頻切頻方式』
,2024/6/5 上午 9:00:10, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -32, 650000, 780000, 0, 0
,2024/6/5 上午 9:00:11, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -26, -27, 866666, 650000, 7, 23
,2024/6/5 上午 9:00:12, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -30, 780000, 650000, 1, 1
,2024/6/5 上午 9:00:14, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -30, 866666, 585110, 6, 21
,2024/6/5 上午 9:00:15, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -30, 866666, 585110, 5, 1
,2024/6/5 上午 9:00:16, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -30, 866666, 585110, 2, 20
,2024/6/5 上午 9:00:17, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -30, 866666, 585110, 7, 22
,2024/6/5 上午 9:00:19, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -30, 866666, 650000, 6, 3
,2024/6/5 上午 9:00:20, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -30, 866666, 650000, 6, 21
,2024/6/5 上午 9:00:21, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -30, 866666, 650000, 5, 1
,2024/6/5 上午 9:00:22, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -30, 866666, 650000, 7, 23
,2024/6/5 上午 9:00:24, 34:4f:3f:70:00:b4(R2-R3), 65, 65, -27, -29, 866666, 780000, 7, 22