

Aug. 2022

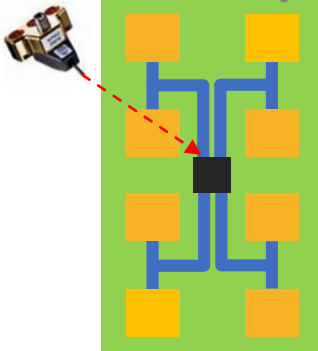


# Axial-Ratio Measurement for LEO Phase Array

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## 天線板量測

Sub-array



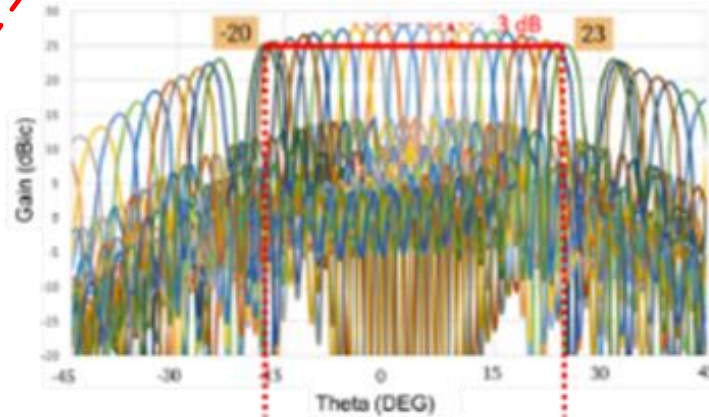
電路板材料參數不均勻

天線特性 ( $D_k / D_f$ ) 不同

Insertion Loss

IC成本高 & debug難

## OTA量測



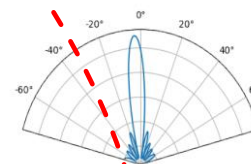
整天線模組量測挑戰：

- 大的靜區 (QZ) 要求
- 衛星通訊圓極化量測
- 追星~3D場型必須
- 環境干擾~5G共存 & G/T

32 × 32 array

- ✓ 大QZ： $0.5\lambda_0 \times 33 = 16.5\lambda_0 \rightarrow$  CATR
- ✓ NF to FF OTA：需要相位進行計算  $\rightarrow$  毫米波量測相位相對誤差大  $\rightarrow$  旋轉饋源天線+CATR
- ✓ 3D beam chart：DUT重量大  $\rightarrow$  專用治具

## 實際使用壓力測試

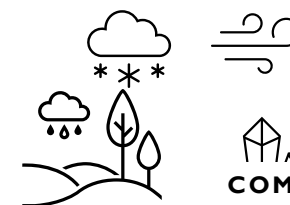


LEO帶來的新挑戰-追星

- Doppler effect (速度)
- Handover (切換)

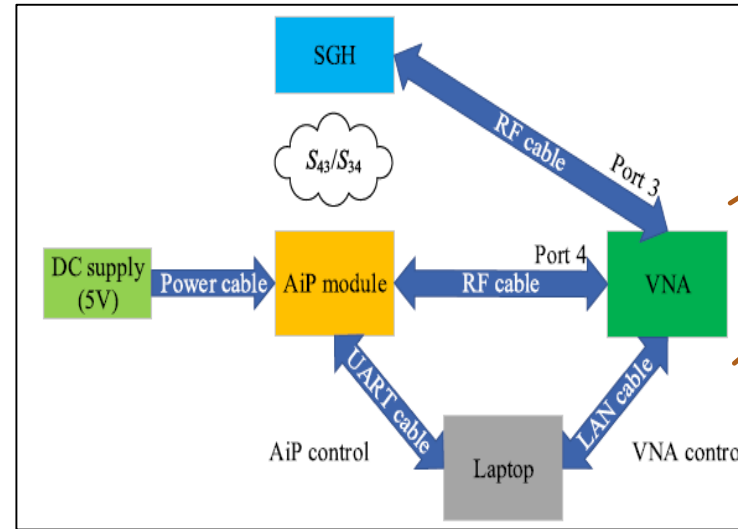
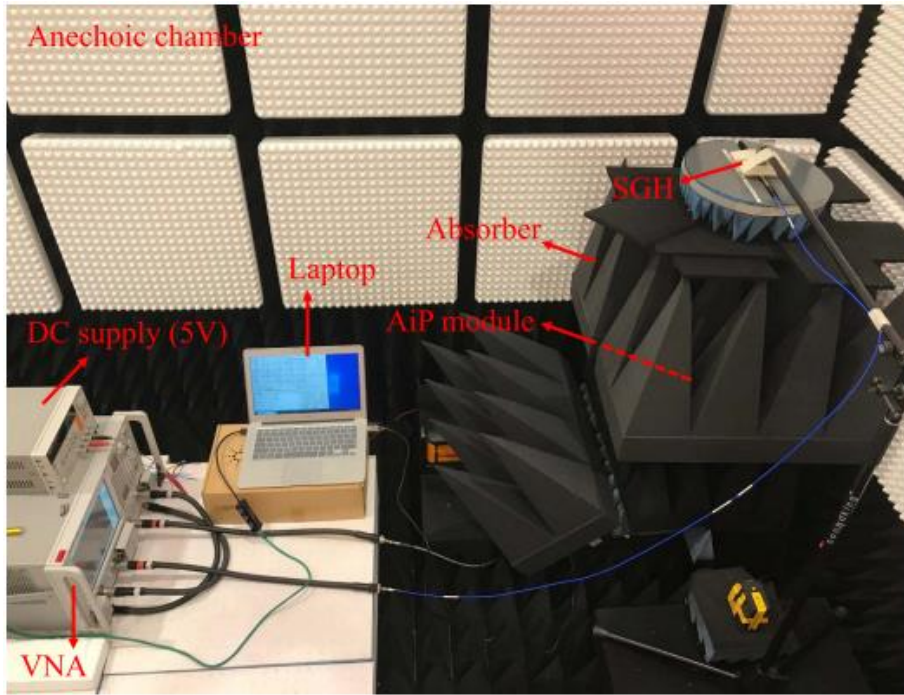
傳統環測箱無內建通訊測試

- 只確定模組沒壞
- 未納入通訊不中斷評估



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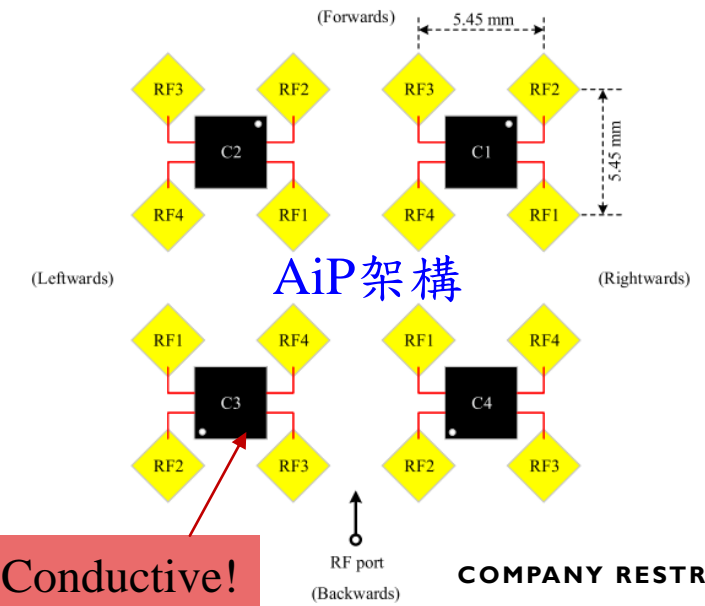
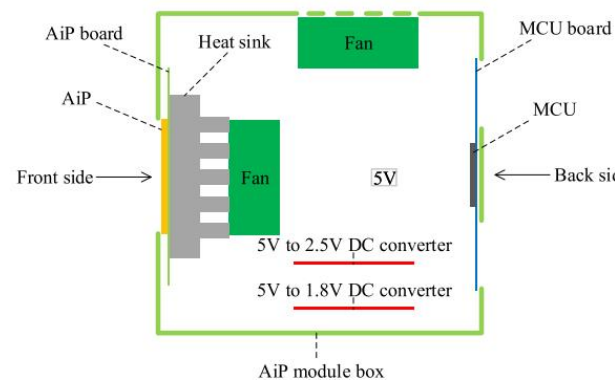
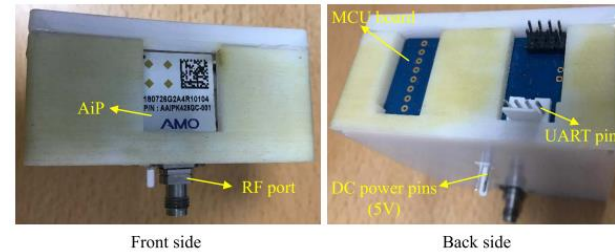
圖片來源：IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT



量測系統

無法分析問題!!

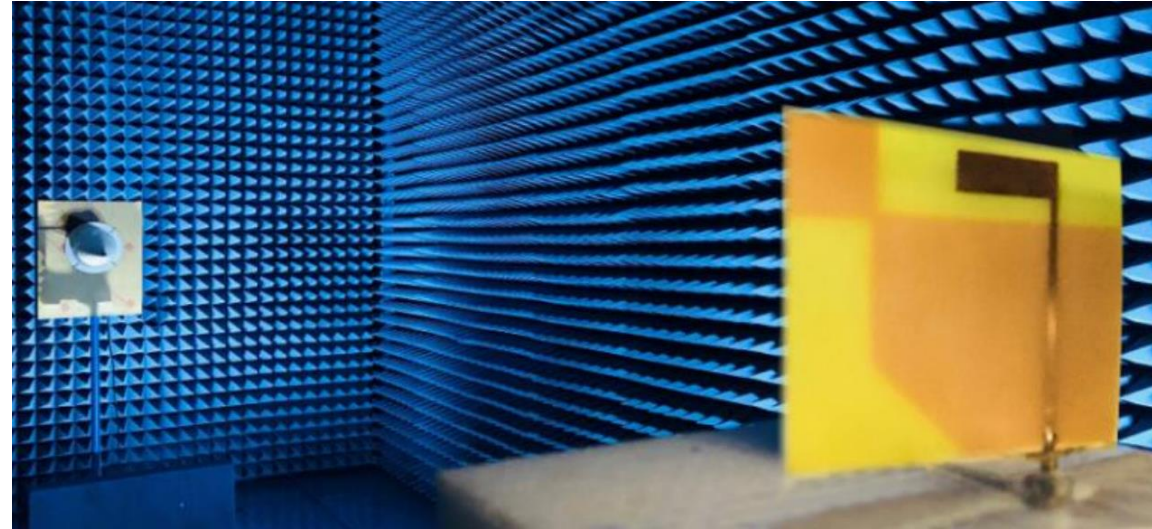
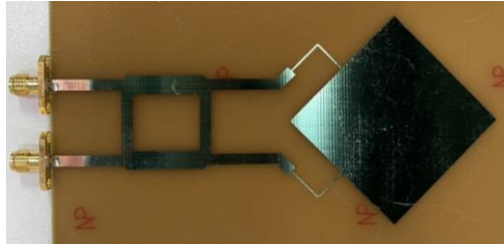
QZ、3D、CP?!



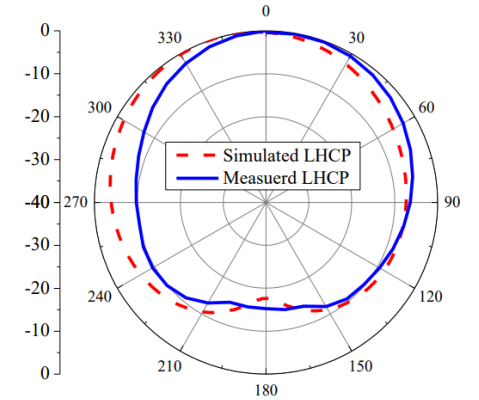
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Boontamchay, Phanuphong, Titipong Lertwiryaprapa, and Chuwong Phongcharoenpanich. 2021. "Inverted L-Shaped CP Patch Antenna with Corner-Truncated Partial Ground Plane Diagonally Adjoined with Square Branch for L-Band Applications" *Sensors* 21, no. 4: 1085.

RHCP  
LHCP



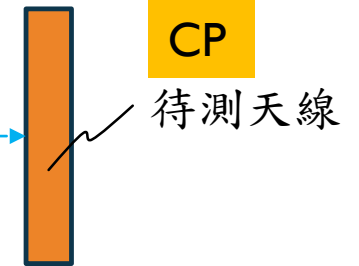
輻射場型範例



Conical Log Spiral Antenna



遠場距離



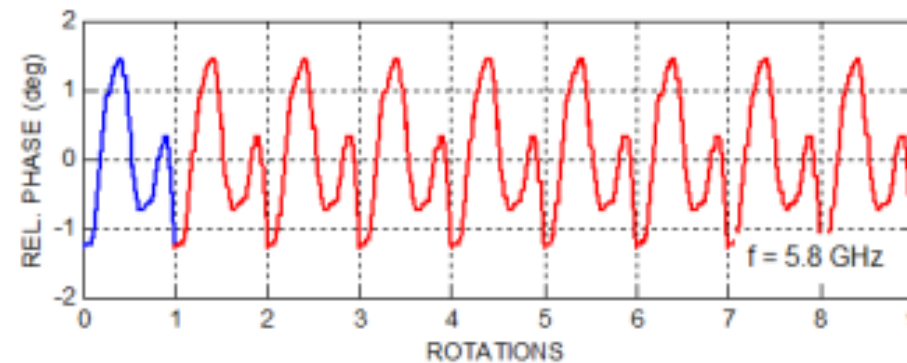
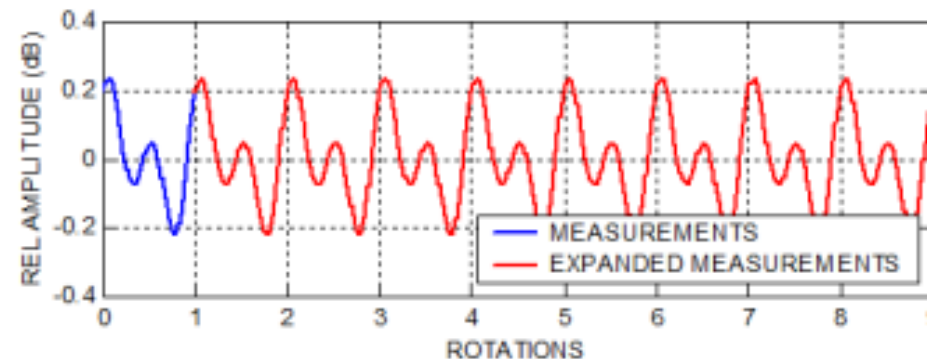
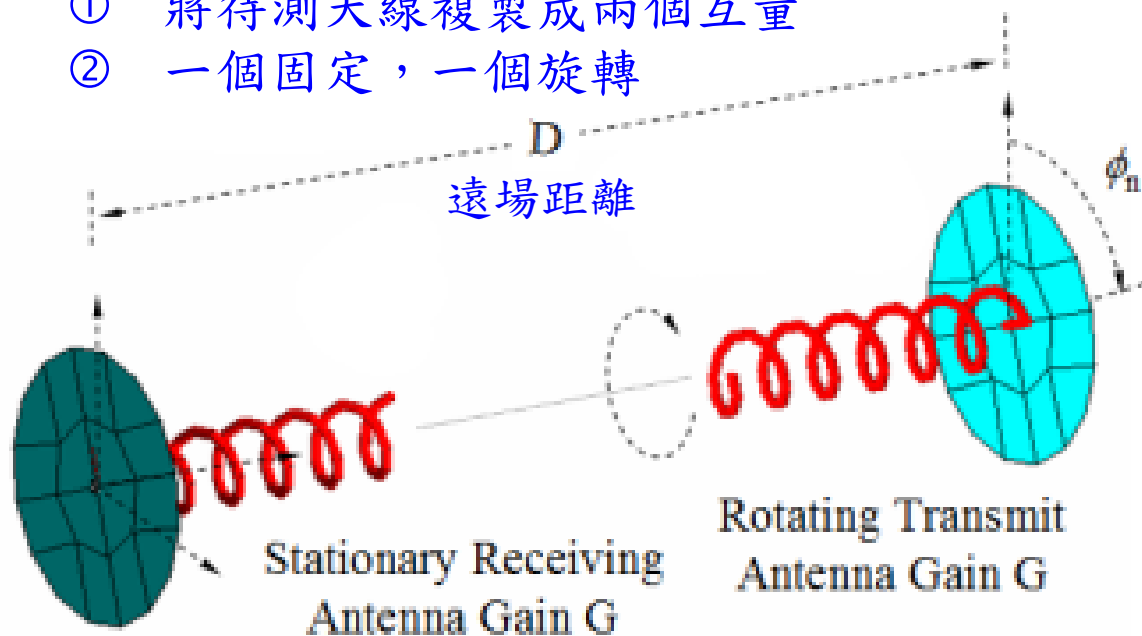
- Feed Antenna :  $E_{\theta}/E_{\phi} \rightarrow$  RHCP/LHCP
- Ideal & wideband CP Feed Antenna?! & QZ?
- AR cal. by

$$Axial\ Ratio = \left| \frac{E_{RHCP} + E_{LHCP}}{E_{RHCP} - E_{LHCP}} \right|$$

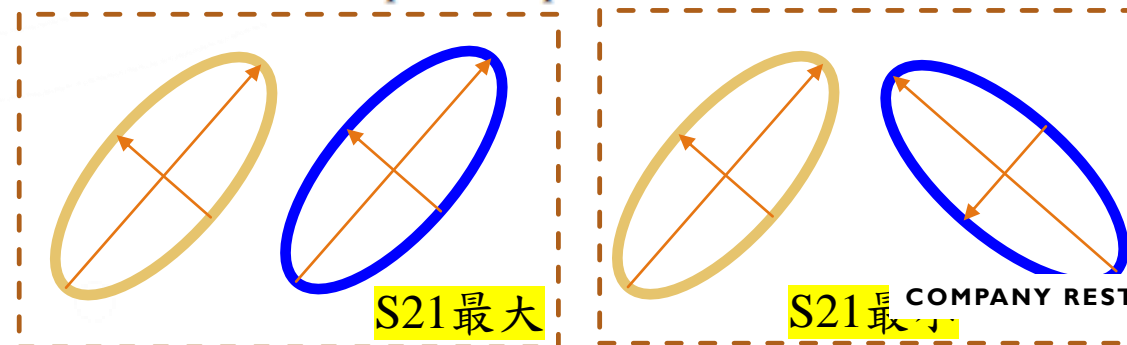
差距 15.3dB ~ AR 3dB

H. M. Aumann and K. A. Tuttle, "A rotating source polarization measurement technique using two circularly polarized antennas," *AMTA 2016 Proceedings*, 2016, pp. 1-4, doi: 10.1109/AMTAP.2016.7806281.

- ① 將待測天線複製成兩個互量
- ② 一個固定，一個旋轉



Example of Expanded  $\tilde{s}_{21}$  Measurements



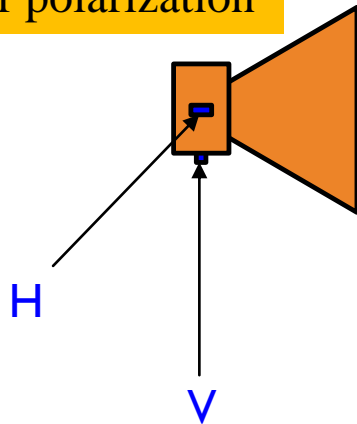
- Ripple → AR
- 雙天線法 → Gain



- QZ?!
- 單一角度?!

Mak, Ka Ming and Kwai Man Luk. "A Circularly Polarized Antenna With Wide Axial Ratio Beamwidth." *IEEE Transactions on Antennas and Propagation* 57 (2009): 3309-3312.

Dual linear polarization



遠場距離

CP

待測天線

$$E_{\theta}/E_{\phi} \rightarrow \text{RHCP/LHCP}$$

$$\text{完美CP} \rightarrow \alpha = 1, \Delta\Phi = 90\text{度}, \text{AR}=1$$

$$AR = \sqrt{\frac{1 + \alpha^2 + \sqrt{(\alpha^4 + 2\alpha^2 \cos(2\Delta\Phi) + 1)}}{1 + \alpha^2 - \sqrt{(\alpha^4 + 2\alpha^2 \cos(2\Delta\Phi) + 1)}}$$

兩線性極化量到的振幅比

兩線性極化量到的兩訊號相位差

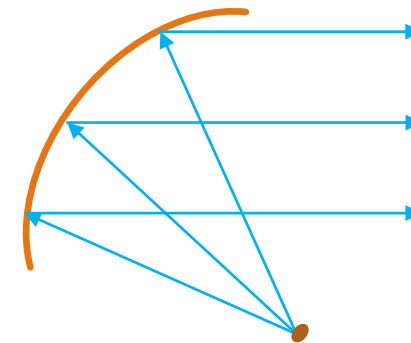
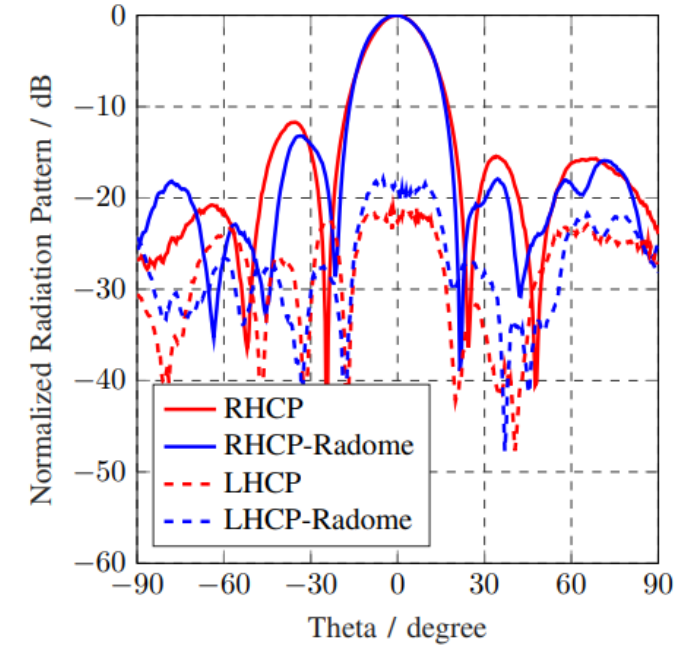
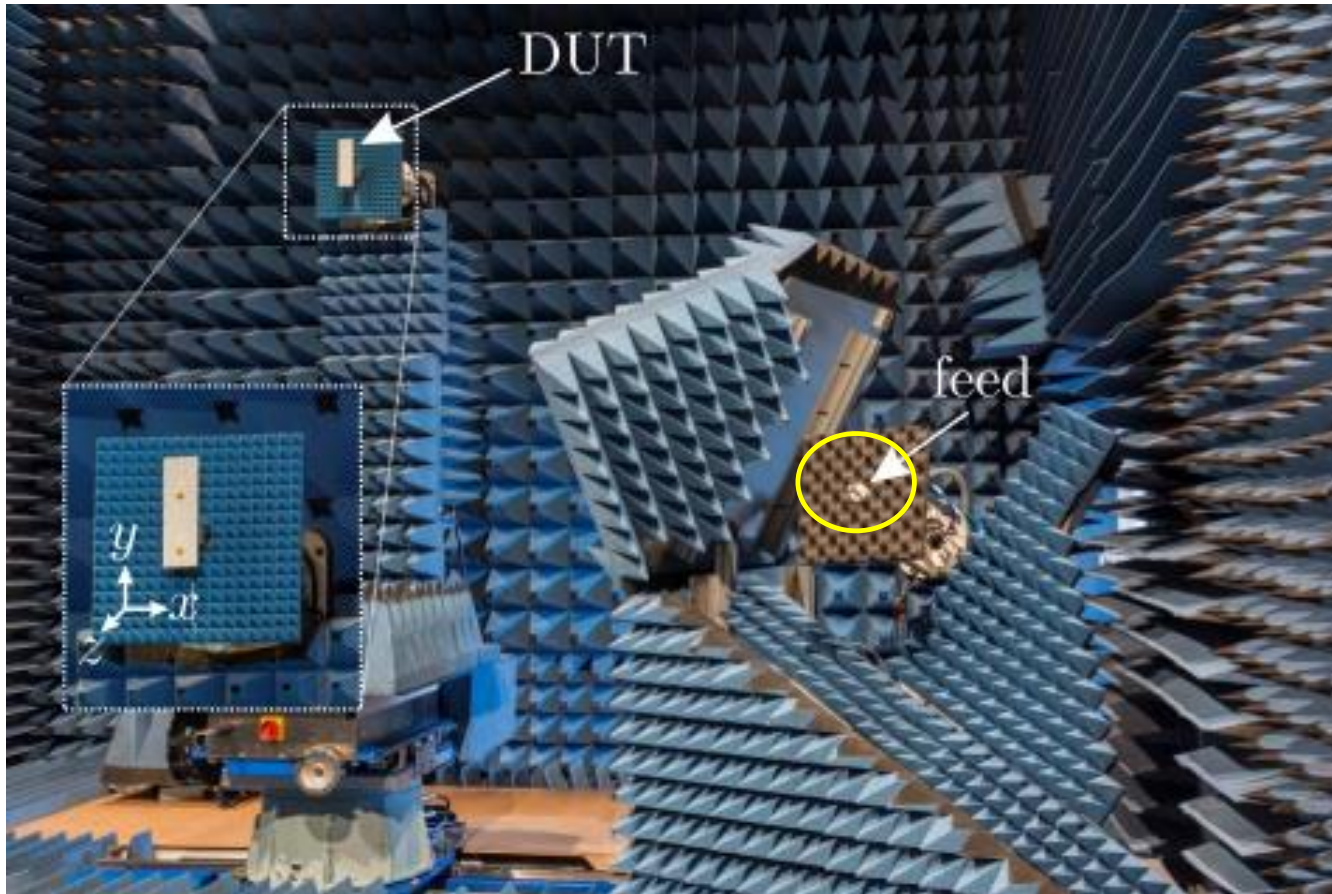
■ QZ!?

■ 相位誤差?!

EX: 以30 GHz算, 1 mm的距離誤差對應36度的空間相位差

A. Al-Bassam, W. Alshrafi and D. Heberling, "A 60 GHz circularly polarized antenna array for line-of-sight train-to-train communication," *2018 11th German Microwave Conference (GeMiC), 2018*, pp. 148-151, doi: 10.23919/GEMIC.2018.8335051.

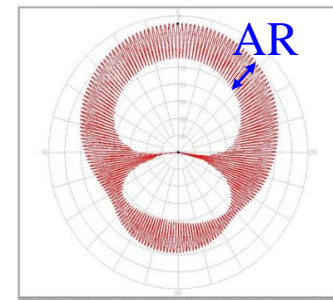
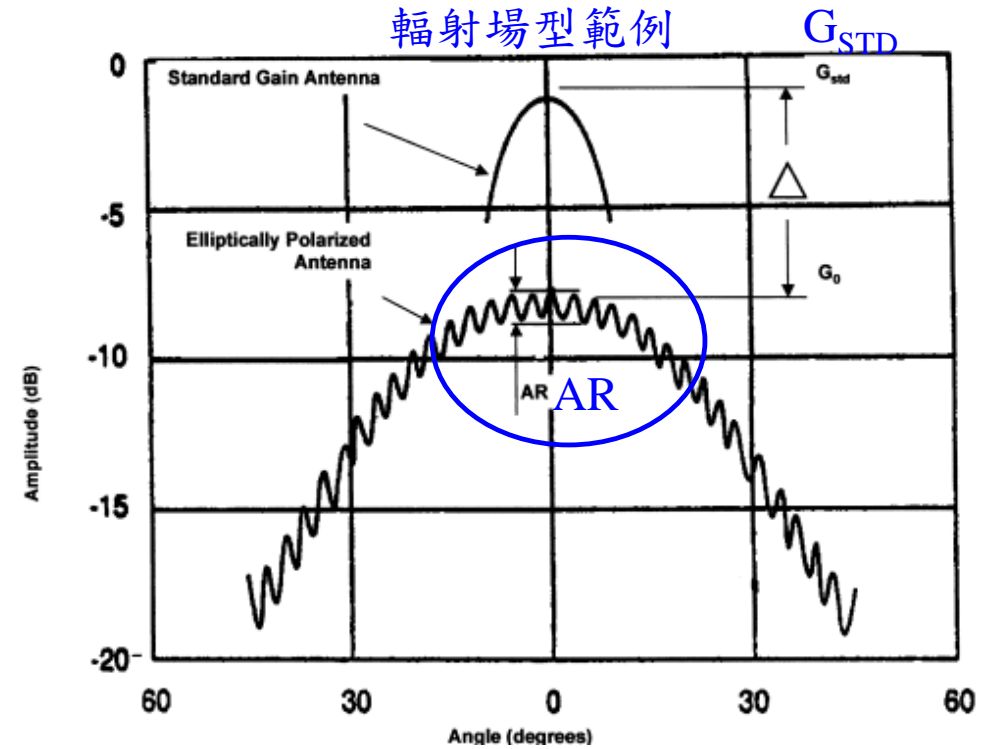
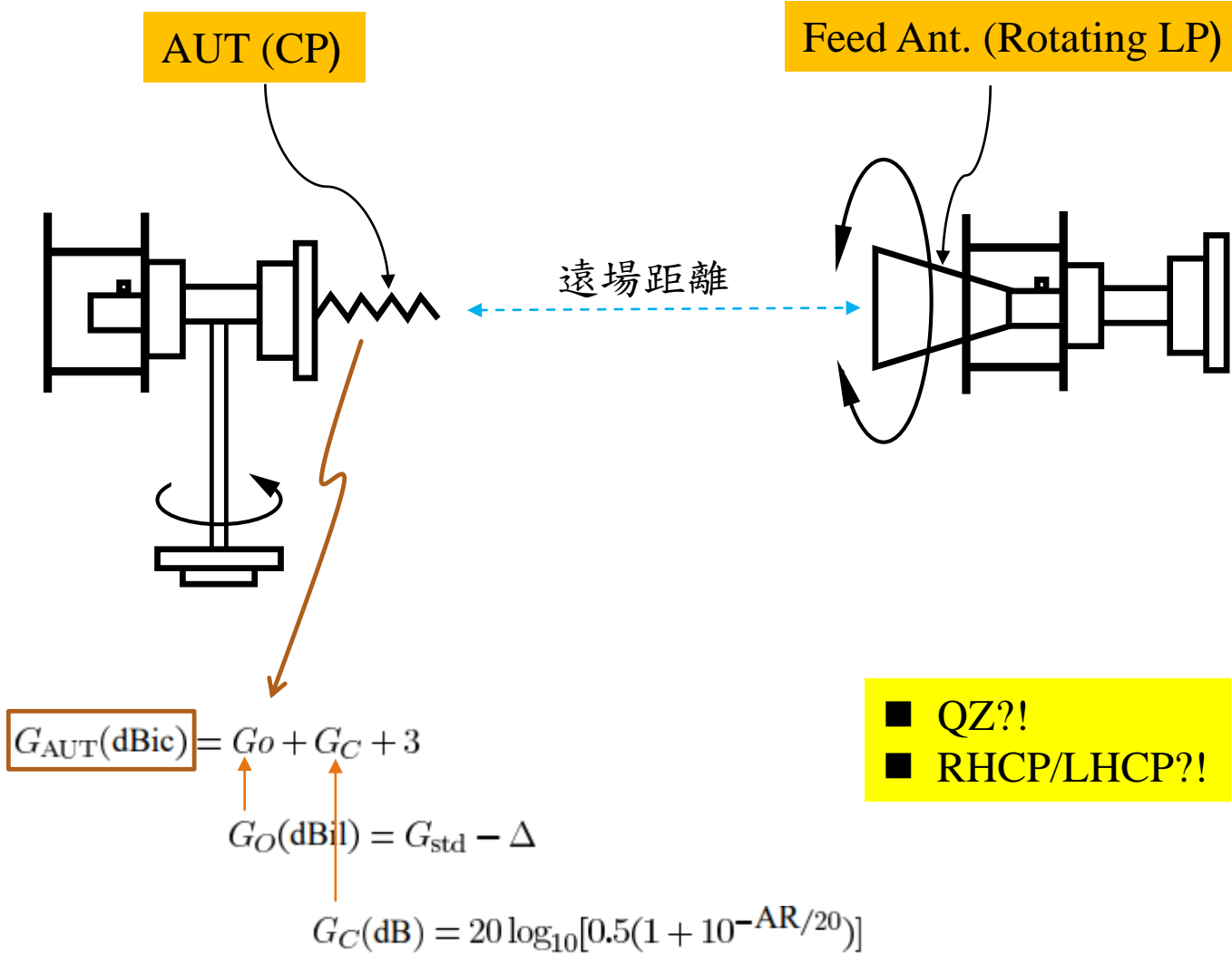
■ 圓極化球面波被反射鏡反射後成為近似均勻平面波，圓極化特性已改變的可能性大?!



RHCP  $\leftrightarrow$  LHCP !?

固定圓極化天線 (feed)

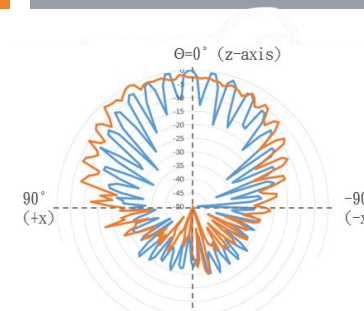
B. Y. Toh, R. Cahill, and V. F. Fusco, "Understanding and measuring circular polarization," *IEEE-Trans. on Education*, Vol. 46, No. 3, Aug. 2003.





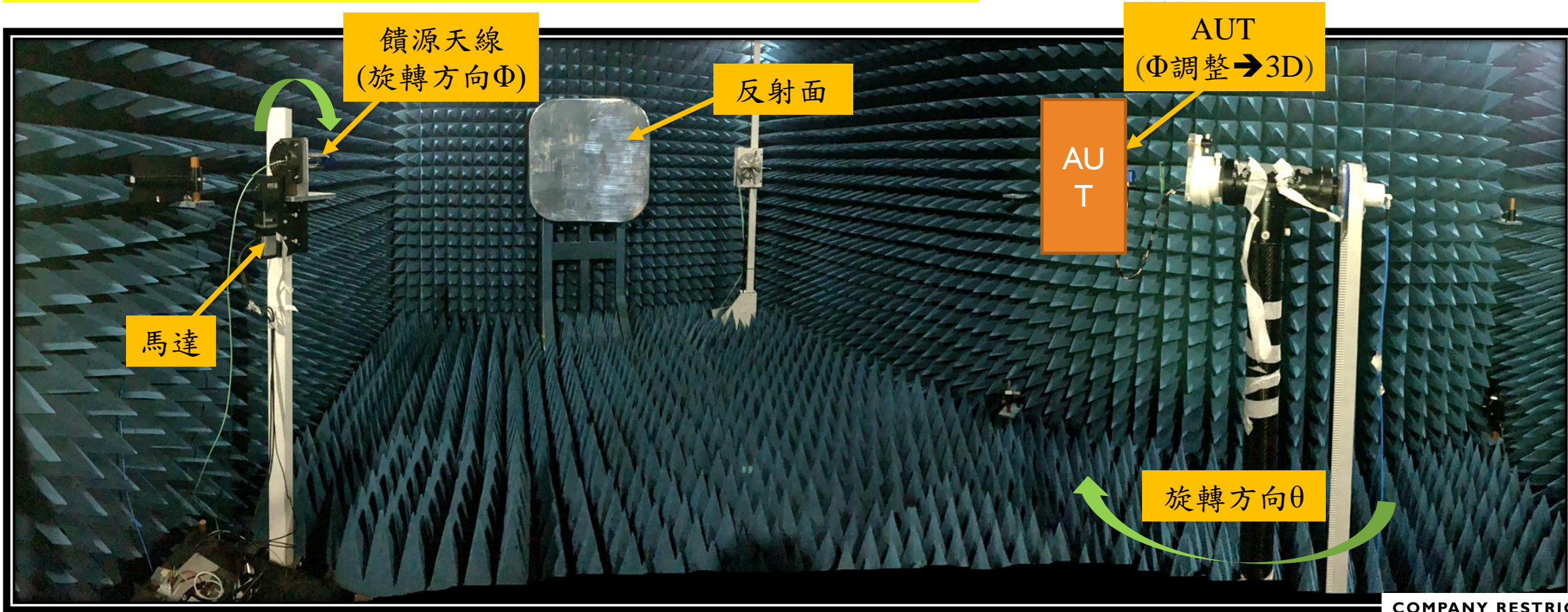
## BWant MS10

- 以縮距場CATR突破傳統DFF的距離要求，LEO相控陣列天線適用
- 不再需要電場相位計算增益
- Feed Ant.不是圓極化天線，而是線性極化



— 圓極化天線

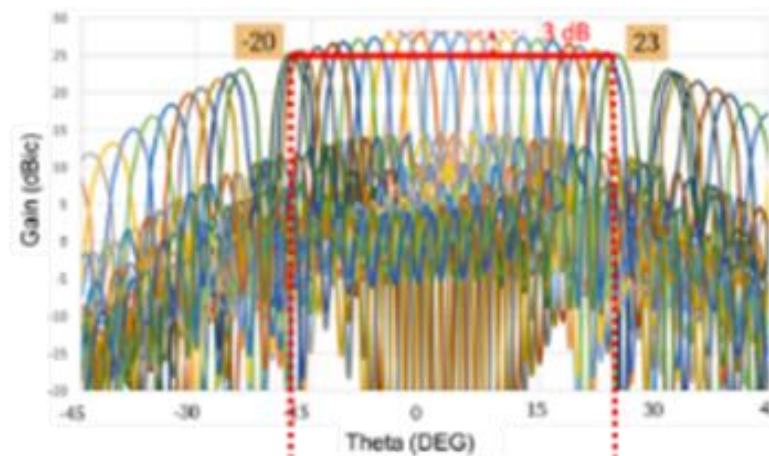
— 線性極化天線



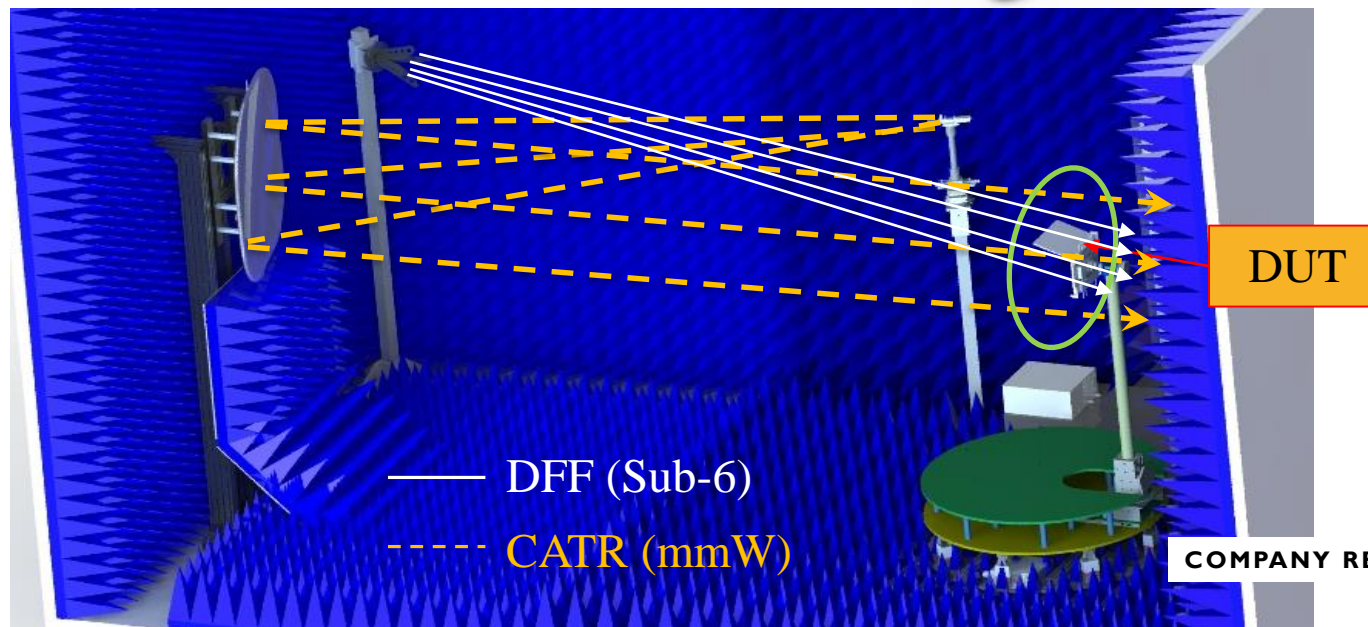
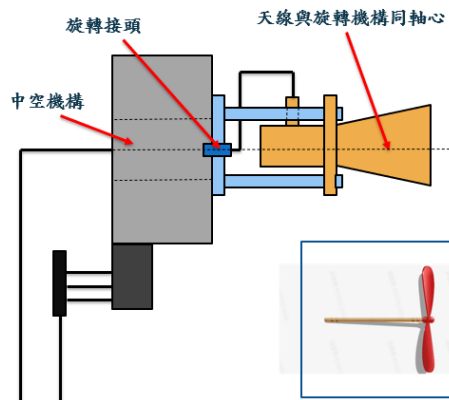
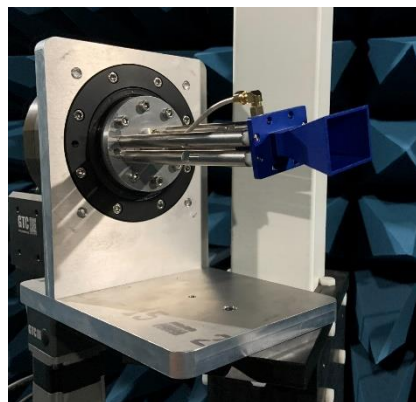
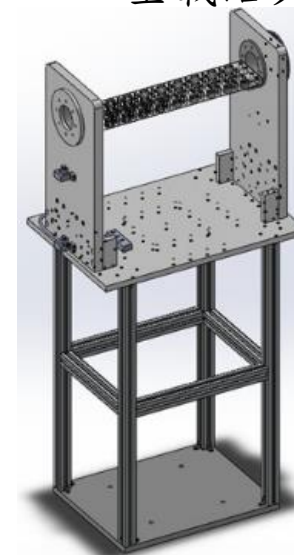
## 相控陣列天線挑戰與解法

- 量測靜區(Quiet Zone)大~**反射鏡**
- 圓極化性能驗證難~**旋轉饋源**
- 天線系統產品重~**治具拆換**
- 5G訊號干擾~**DFF+CATR**
- **3D CP Beam Chart**

Ripple Amp. → Beam Chart : CP



3D重載治具



- ✓ **CATR+旋轉饋源OTA系統**
- ✓ **DFF+IFF : DFF測試5G影響**

暗室類型	饋源天線	優點	缺點
直接遠場 (DFF)	圓極化 (不動)	<ul style="list-style-type: none"> <li>■ 不需要用到電場相位即可計算出輻射場型</li> <li>■ 避免毫米波相位誤差</li> </ul>	<ul style="list-style-type: none"> <li>■ 高頻+大天線→QZ不易達成</li> <li>■ LEO相控陣列→毫米波+大天線</li> </ul>
	單線性極化 (連續旋轉)		
	兩相同待測圓極化天線互量 (一連續旋轉，一不動)		
	雙線性極化 (不動)	<ul style="list-style-type: none"> <li>■ 既有量線性極化的OTA系統可沿用</li> </ul>	<ul style="list-style-type: none"> <li>■ 需要相位值將兩線性極化數值轉圓極化</li> <li>■ 相位值誤差大</li> </ul>
縮距場 (CATR)	圓極化 (不動)	<ul style="list-style-type: none"> <li>■ 省空間</li> </ul>	<ul style="list-style-type: none"> <li>■ 反射鏡影響CP軸比，導致誤差</li> </ul>
	單線性極化 (連續旋轉)	<ul style="list-style-type: none"> <li>■ 適合高頻大尺寸天線</li> <li>■ 不需要用到電場相位即可得到輻射場型</li> </ul>	<ul style="list-style-type: none"> <li>■ 輻射場型呈刺針狀，較不直觀→換算為dBic</li> </ul>
近場 (NF)	單線性極化 (連續旋轉)	<ul style="list-style-type: none"> <li>■ 省空間</li> </ul>	<ul style="list-style-type: none"> <li>■ NF→FF，計算耗時</li> <li>■ 場型生成需「振幅+相位計算」</li> <li>■ 毫米波相位誤差大</li> </ul>
	單線性極化 (不動，V/H分別量)		
	雙線性極化 (不動，V/H同時量)		

一個低軌衛星天線模組是整合『千顆天線』、『低損載板』、『百顆RFIC』的高度工藝，故如何抽絲剝繭量測各項元件獨立與組合後的參數更決定了最終成品的效能，其挑戰如下：

過去所沒有的挑戰

- ① IC成本高/性能難驗證~百顆 IC 各自的功率放大器(PA/LNA)及相移器(PS)存在不一致性，Ka-band的毫米波頻段難度更遠大於中/低軌衛星頻段 MW5
- ② 電路板高頻性能驗證~頻率高至Ka-band，即使同片板材但不同位置的電參數 (Dk/Df) 仍會不一致
- ③ 相控陣列天線校正~因此必須經由實測並修正天線模組beam chart
- ④ 大型圓極化陣列天線OTA~使用近場量測時間長且須有準確相位量測結果，所以不僅量測費時且無法分析含調變或AUT獨立傳輸的系統性能狀況 MS10
- ⑤ 環境干擾效應評估~5G FR1對LEO干擾/共存及G/T參數量測
- ⑥ 模擬衛星移動都普勒效應測試~測試訊號必須如同低軌衛星高速移動時之狀態 MW6
- ⑦ 衛星切換測試~利用地面衛星天線之動態波束追蹤天空衛星間的切換狀態 動態環測箱
- ⑧ 實際使用場景效應~環境溫溼度效應及環境干擾問題對衛星通訊性能影響大 COMPANY RESTRICTED



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