

1

(a)



(c)

Estimation^ result 是-0.2996513450181178 。

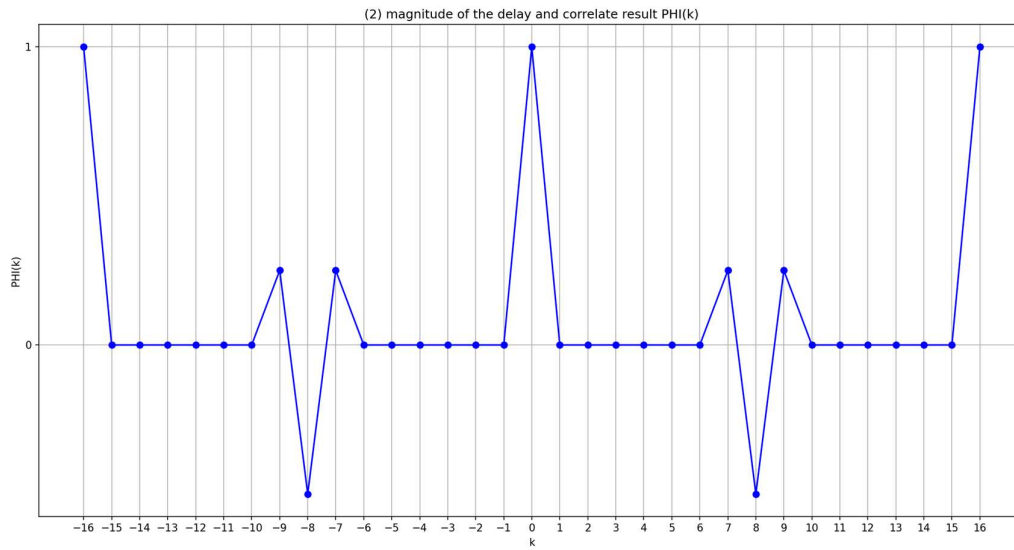
我們可以看到所估出的 ϵ^* 的值和當初 ϵ 是 5.7 有差距，因此有 **ambiguity phenomenon**。我覺得這樣的估計還是不太 **reasonable**，因為和原來預計所要產生的 y_n 並沒有產生一個週期性的 **phase** 平移，造成所要 **receive** 的 **signal** 和原來預期的不一樣。

2.

請執行 python Q2.py

$\Phi(k)$:

[1.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.25, -0.5, 0.25, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.25, -0.5, 0.25, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0]



3.

請執行 `python Q3.py`

(a)

我們可以推得在 `z65~z86` 之間的 `received signal` 不會有含到 `user data` 的部分，因此 `m` 的 `maximum index range` 是在 65 到 86 之間。

主要是因為最大 `delay` 的第一個 `midamble` 位置在 65，而沒有 `delay` 的最後一個 `midamble` 在 86 的位置。

(b)

results of estimated channel impulse response:

`h0: (0.19555626863177578+0.09450246634006729j)`

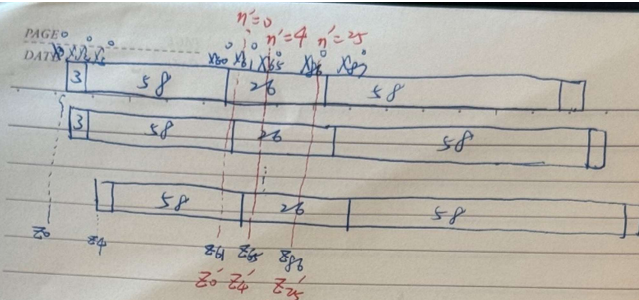
`h1: (-0.5807064459025967-0.5242379240736381j)`

`h2: (0.16252940896141396-0.27095231224407057j)`

`h3: (0.43809035390307516-0.11138343577812437j)`

`h4: (0.0201970910585785+0.19029802306107554j)`

以下是我所用到的 `sequence`。如果是指 `x` 的 `sequence si`，我用的 `x sequence` 就是 `midamble` 的第 4~19。因此 `a=4, b=19`。`z sequence` 則是從 `z4` 到 `z23` 都有用到。



$$z_{65} \rightarrow z_4 = h_0 x_4 + h_1 x_3 + h_2 x_2 + h_3 x_1 + h_4 x_0$$

$$z_{66} \rightarrow z_5 = h_0 x_5 + h_1 x_4 + h_2 x_3 + h_3 x_2 + h_4 x_1$$

$$z_{86} \rightarrow z_{25} = h_0 x_{25} + h_1 x_{24} + h_2 x_{23} + h_3 x_{22} + h_4 x_{21}$$

$N=16$

$$\begin{aligned} (z_4' x_4^* + z_5' x_5^* + \dots + z_{19}' x_{19}^*) &= h_0 (x_4' x_4^* + x_5' x_5^* + \dots + x_{19}' x_{19}^*) \\ &+ h_1 (x_3' x_4^* + x_4' x_5^* + \dots + x_{18}' x_{19}^*) \\ &+ \dots \\ &+ h_4 (x_0' x_4^* + x_1' x_5^* + \dots + x_{15}' x_{19}^*) \\ (z_4' x_4^* + z_5' x_5^* + \dots + z_{19}' x_{19}^*) &= h_0 (x_4' x_4^* + x_5' x_5^* + \dots + x_{19}' x_{19}^*) + 0 \end{aligned}$$

$$\frac{(z_5' x_4^* + z_6' x_5^* + \dots + z_{20}' x_{19}^*)}{N} = h_1$$

$$\frac{(z_6' x_4^* + z_7' x_5^* + \dots + z_{21}' x_{19}^*)}{N} = h_2$$

$$\frac{(z_7' x_4^* + z_8' x_5^* + \dots + z_{22}' x_{19}^*)}{N} = h_3$$

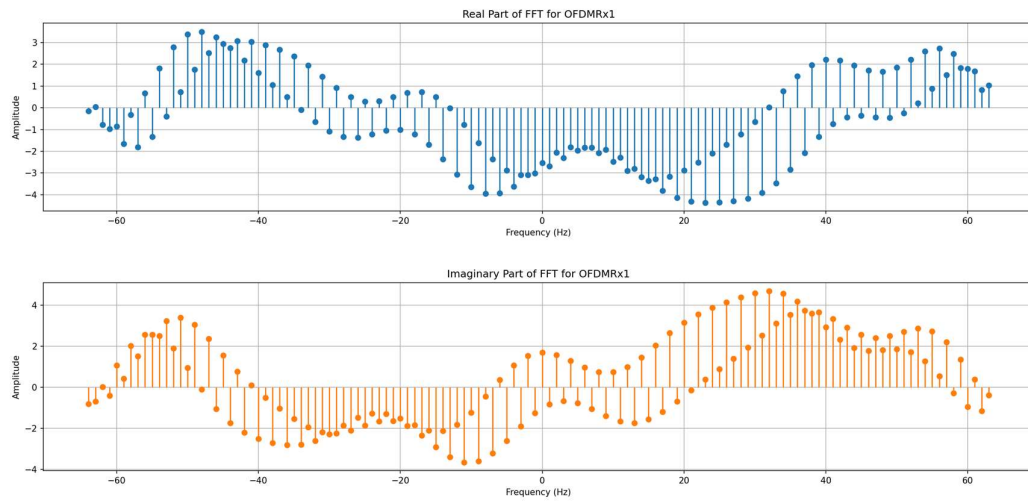
$$\frac{(z_8' x_4^* + z_9' x_5^* + \dots + z_{23}' x_{19}^*)}{N} = h_4$$

4.

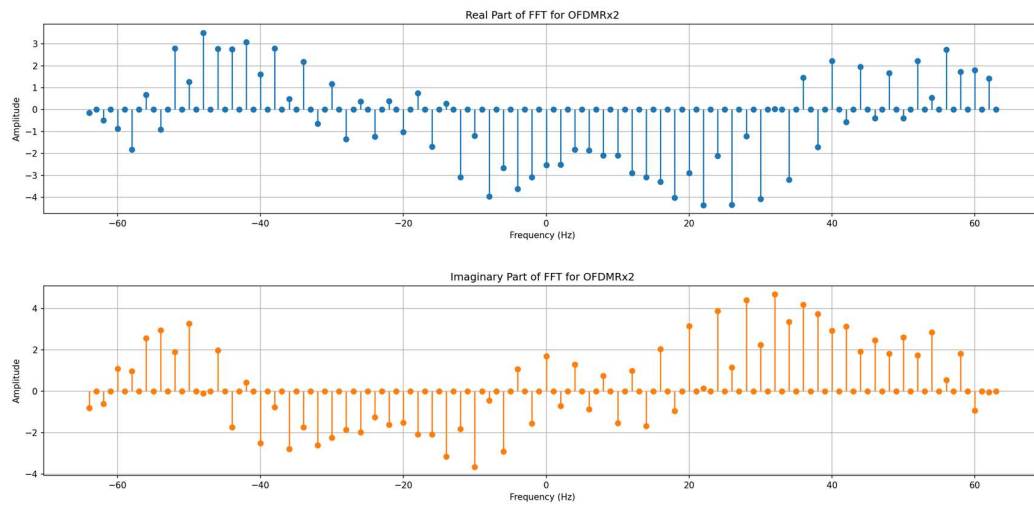
請執行 `python Q4.py`

(a)

OFDMRx1:

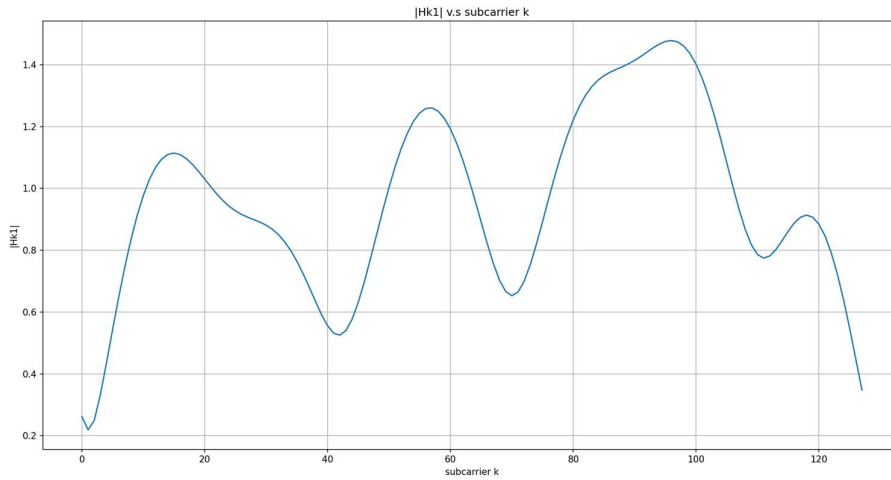


OFDMRx2:



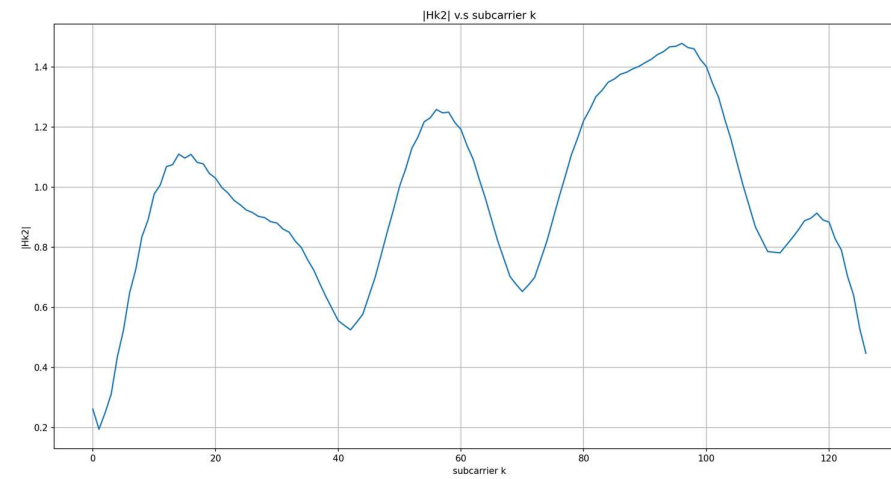
(b)

$|H_{k1}|$ versus subcarrier k :



(c)

$|H_{k2}|$ versus subcarrier k :



(d)

Magnitude of $|H_{k1} - H_{k2}|$:

```
[0.0, 0.024319033516053794, 1.5515838457795457e-16, 0.024910317271693554, 0.0, 0.025033532645265515, 2.3592239273284576e-16, 0.024653927475182854, 0.0, 0.02373867038183834, 2.482534153247273e-16, 0.02226700242023319, 0.0, 0.020243303751139297, 3.189627710442956e-16, 0.017709591260117983, 0.0, 0.01475502506465952, 1.5700924586837752e-16, 0.011523121899201308, 0.0, 0.008226827582537372, 4.47545209131181e-16, 0.005224872285612619, 0.0, 0.003395728834807552, 3.3306690738754696e-16, 0.003951161287104697, 0.0, 0.005638999178960911, 3.3306690738754696e-16, 0.007198549013111733, 0.0, 0.008321595129442827, 3.1401849173675503e-16, 0.009000496201151297, 0.0, 0.009356757659099853, 5.55115123125783e-17, 0.00958069803979247, 0.0, 0.009867095352681399, 0.0, 0.010337727919302464, 0.0, 0.010993813885741905, 2.7755575615628914e-16, 0.011736883421366029, 0.0, 0.012432872216686687, 5.55115123125783e-17, 0.012967678397090959, 0.0, 0.0132733466302876, 1.3270624591222574e-16, 0.01332435518977816, 0.0, 0.0131673480011831205, 1.1102230246251565e-16, 0.012828726354804306, 0.0, 0.012381051482661774, 1.1102230246251565e-16, 0.01189197284826889, 0.0, 0.011424095906636875, 2.2887833992611187e-16, 0.01102693512793159, 0.0, 0.010726242694597064, 2.0014830212433605e-16, 0.010511770358774351, 0.0, 0.010330207544140315, 1.5700924586837752e-16, 0.010090330802734387, 0.0, 0.009681052898422268, 2.220446049250313e-16, 0.008995387895244822, 0.0, 0.00795320125056157, 7.021666937153402e-16, 0.006519615602106159, 0.0, 0.004723723795070113, 3.1401849173675503e-16, 0.0027224846265076433, 0.0, 0.0015094905976699826, 8.881784197001252e-16, 0.003101821913826192, 0.0, 0.005406755675018424, 4.440892098500626e-16, 0.0075944177260963384, 0.0, 0.009433358452049298, 1.1102230246251565e-16, 0.010783195264476773, 0.0, 0.011563378046202393, 4.002966042486721e-16, 0.011760989157941265, 0.0, 0.011446409787056716, 2.482534153247273e-16, 0.01079550837120201, 0.0, 0.010114016845501384, 3.1401849173675503e-16, 0.009821913277300554, 0.0, 0.010296261805540463, 1.1102230246251565e-16, 0.011617042219508029, 0.0, 0.013550018546945899, 2.423651445728339e-16, 0.01576947359035705, 0.0, 0.01800705835520922, 1.5700924586837752e-16, 0.02007769445549823, 0.0, 0.021863405569121426, 1.942890293094024e-16]
```

$|H_{k1} - H_{k2}|$ vs subcarrier k :

