Wind Spiral & Flight Procedure Design

Liu Chongjun
2021.10.18

Self-introduction

Liu Chongjun

Age: 46

Career:

1996.8 - 2009.11

Aeronautical Information Service

2009.11 - 2021.10

Flight Procedure Design

FPD Project:

2010 Xianyang International Airport Project

2012 Lanzhou International Airport Project

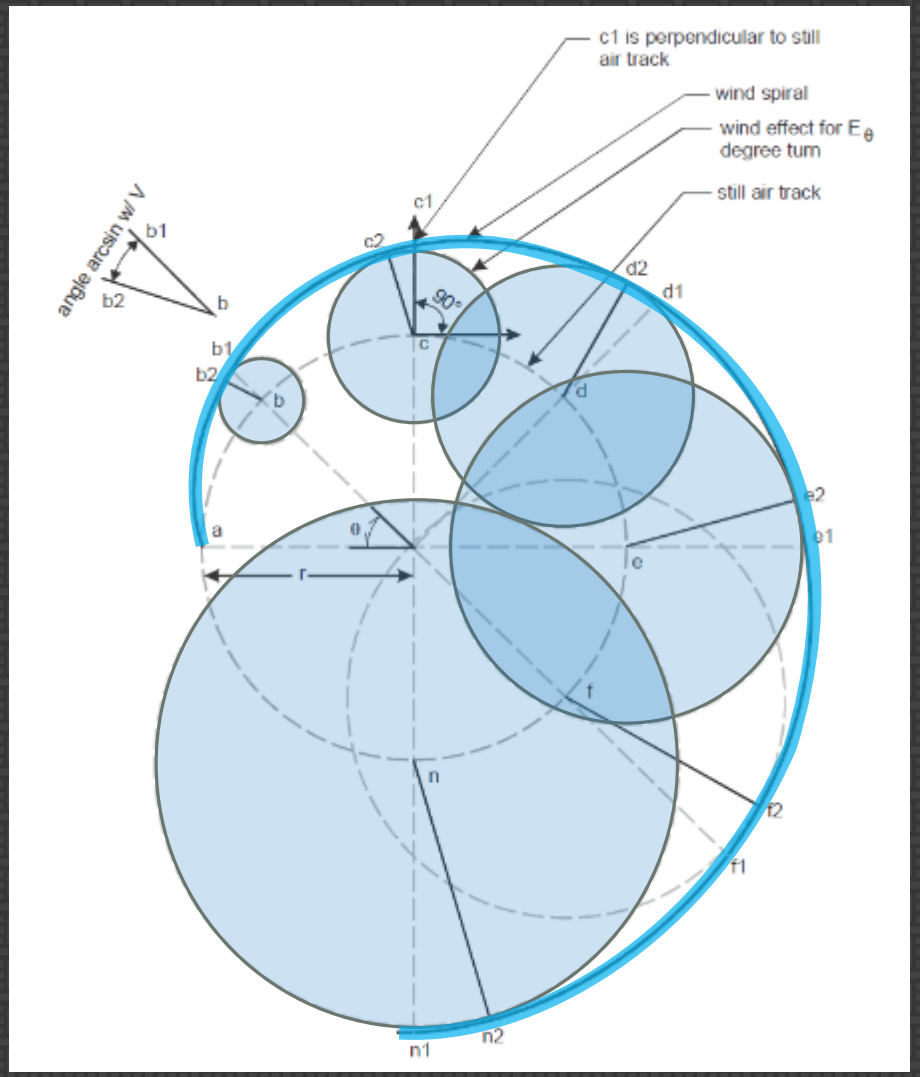
2010-2021 FPD training for ATC

Content

Part I

Definition of Wind Spiral

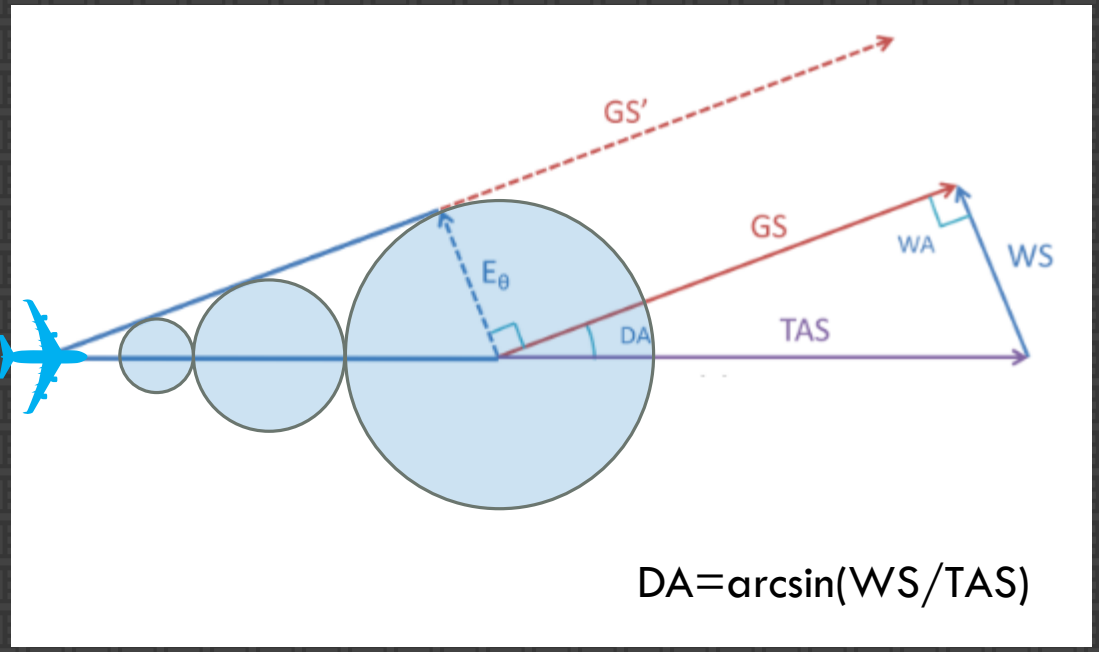
Wind Spiral in DOC8168



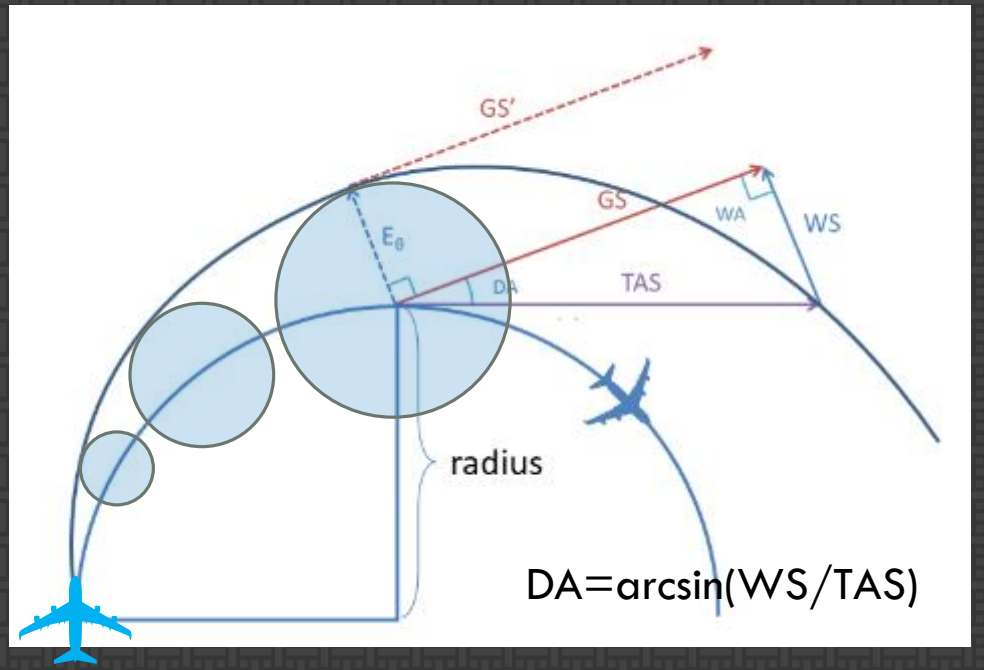
$$E_\theta = \frac{WS}{R} * \theta$$

WS	Wind Speed
R	Rate of Turn
θ	Angle of Turn
Eθ	Distance from the nominal track

Eθ in Different flight path

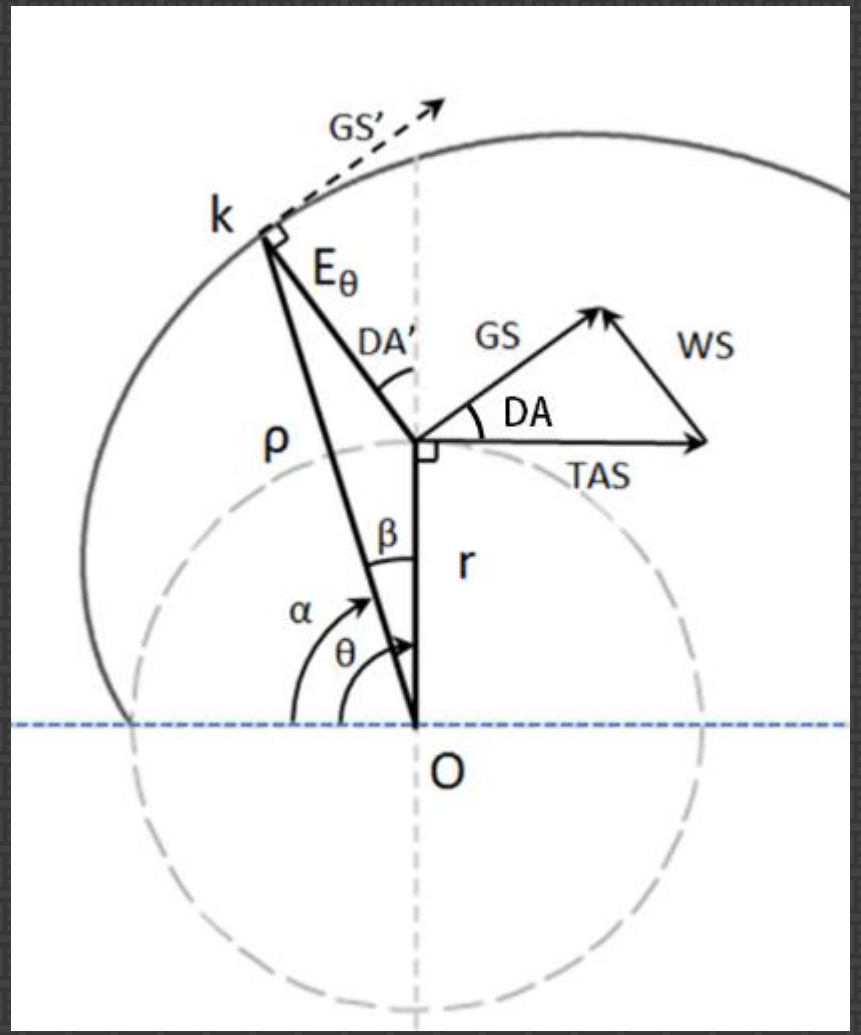


Eθ in straight line flight



Eθ in circle flight

Basic Formula in polar coordinate system

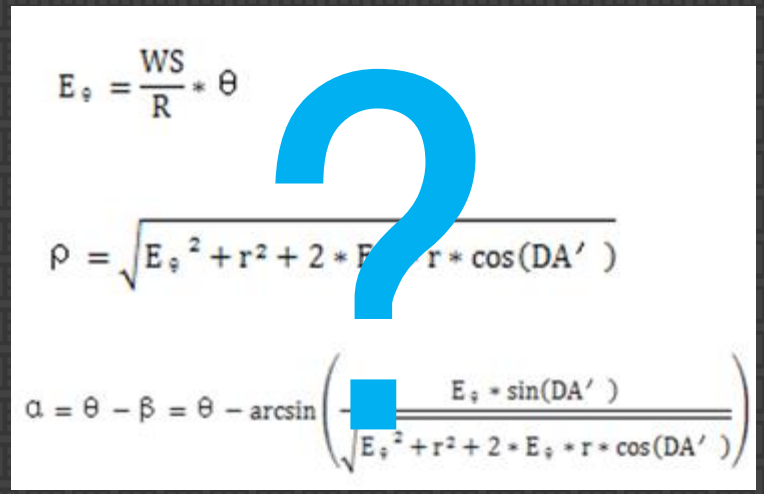


$$E_\varphi = \frac{WS}{R} * \theta$$

$$\rho = \sqrt{E_\varphi{}^2 + r^2 + 2 * E_\varphi * r * \cos(DA')}$$

$$\alpha = \theta - \beta = \theta - \arcsin\left(\frac{E_\varphi * \sin(DA')}{\sqrt{E_\varphi{}^2 + r^2 + 2 * E_\varphi * r * \cos(DA')}}\right)$$

More questions



1. Does it right? How to prove it?

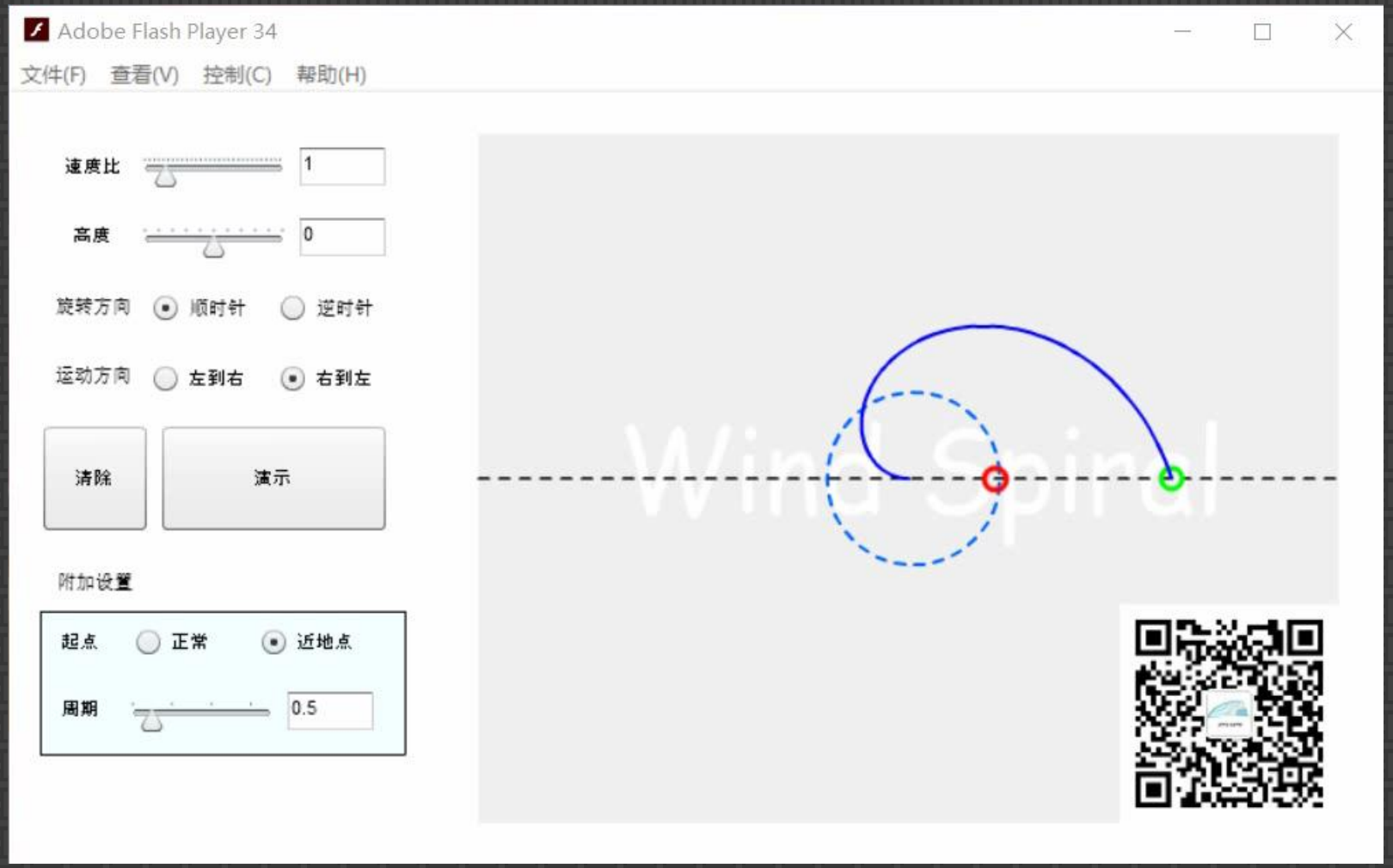
2. How to calculate Expand spiral? how to get tangent line of spiral? Is it same in clockwise or count clockwise?

3. What’s the relation between the wind spiral and other spiral?

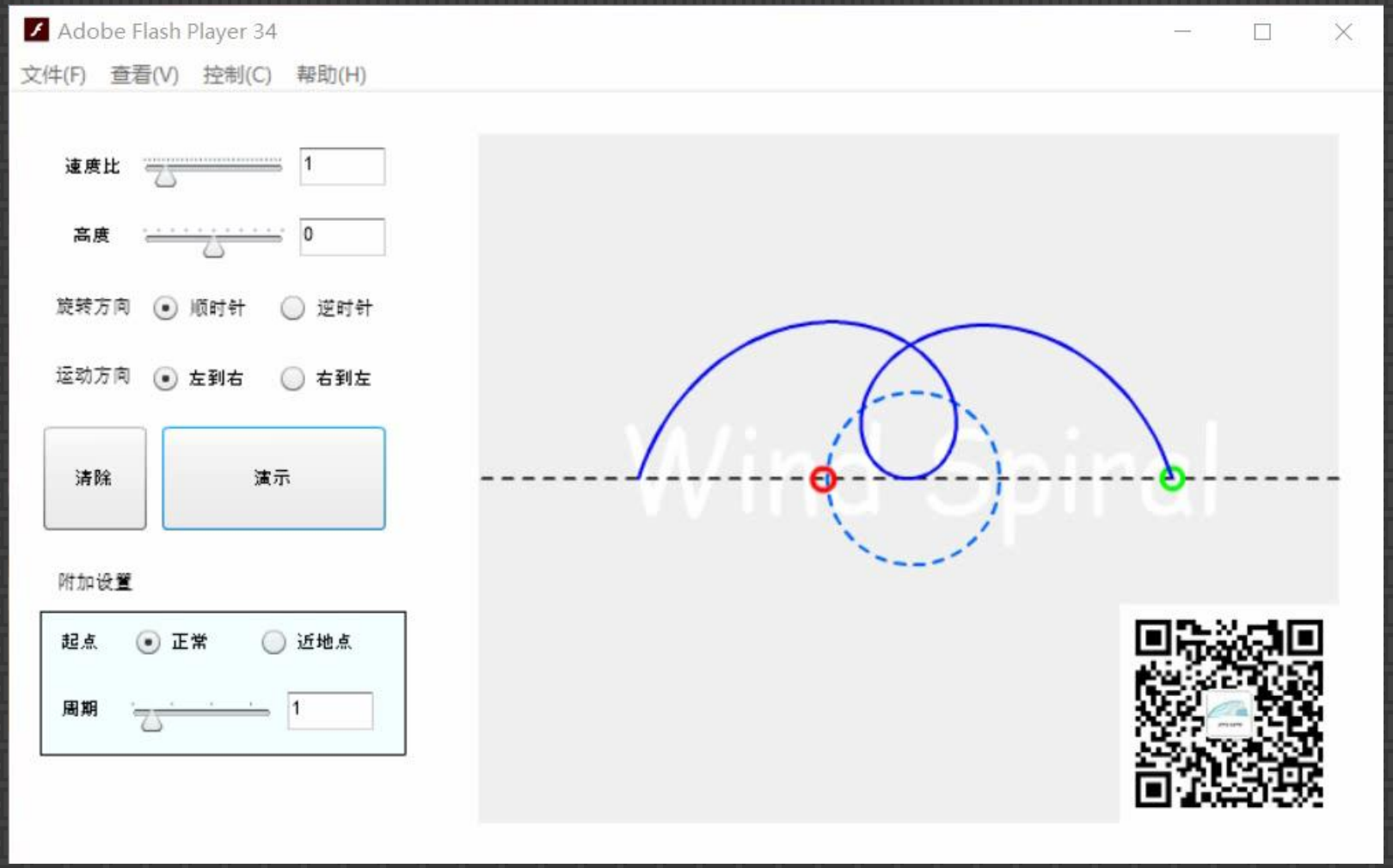
Part II

Concept of Equidistant Spiral

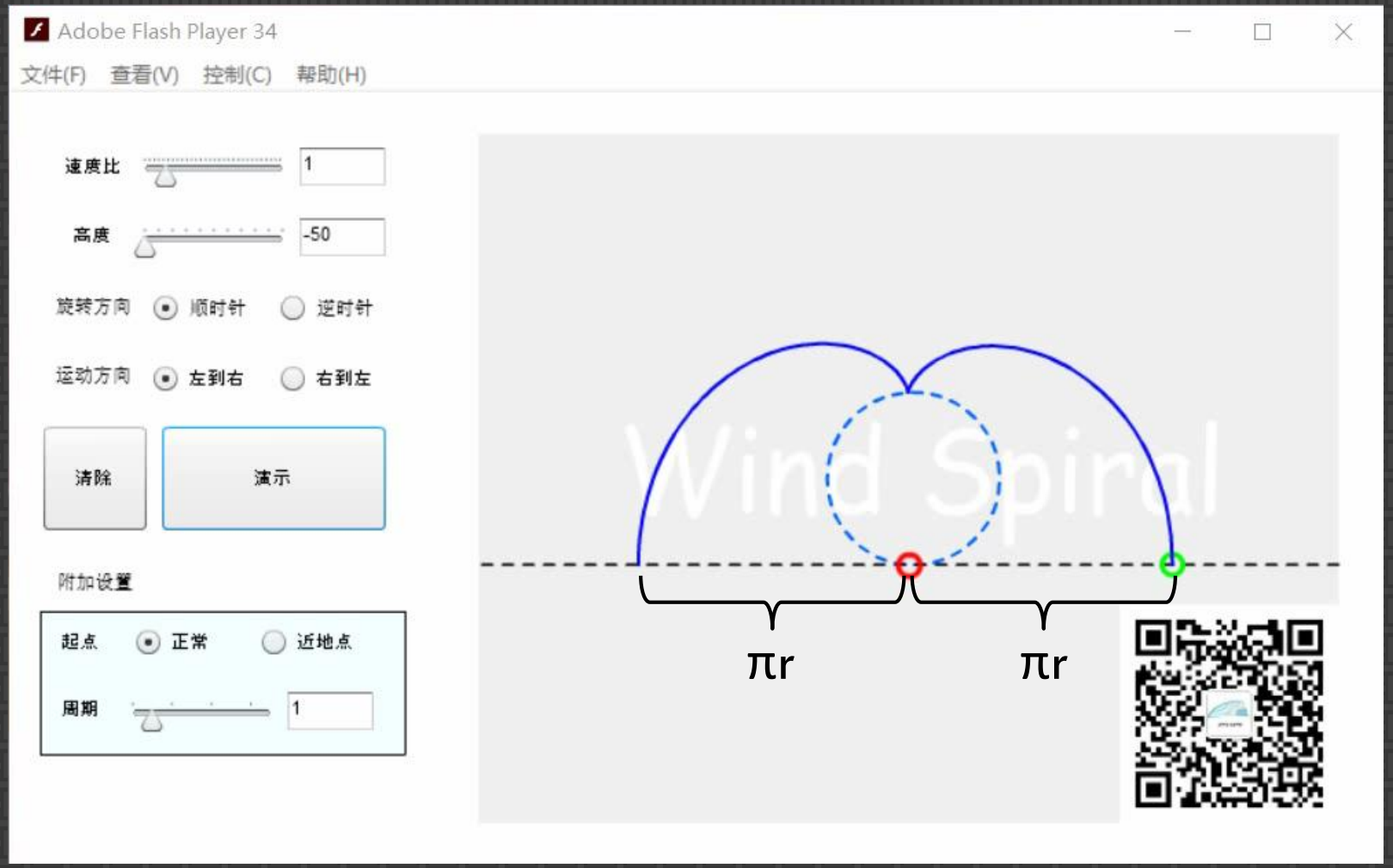
Original Archimedes spiral



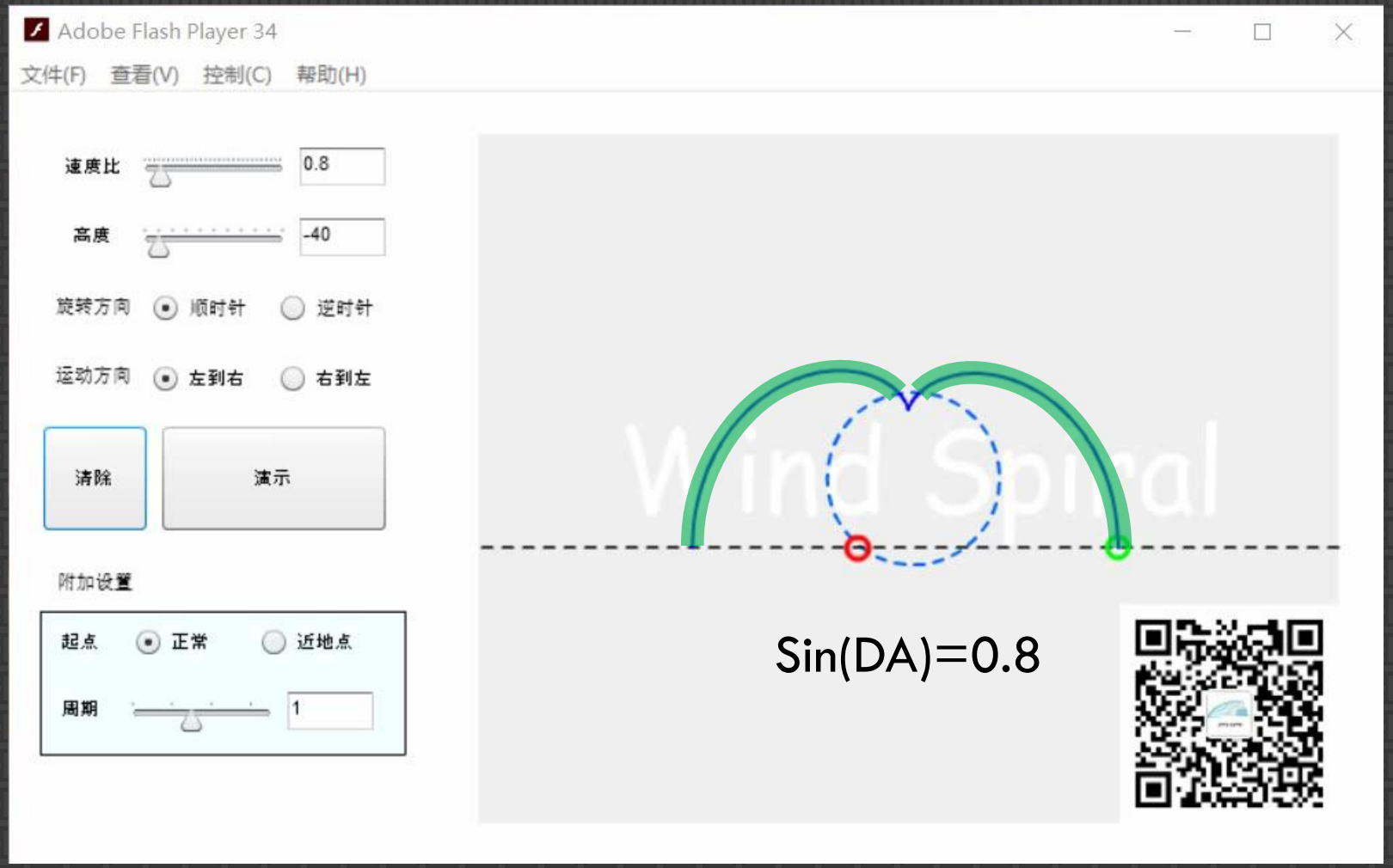
Full Archimedes spiral



Involute curve

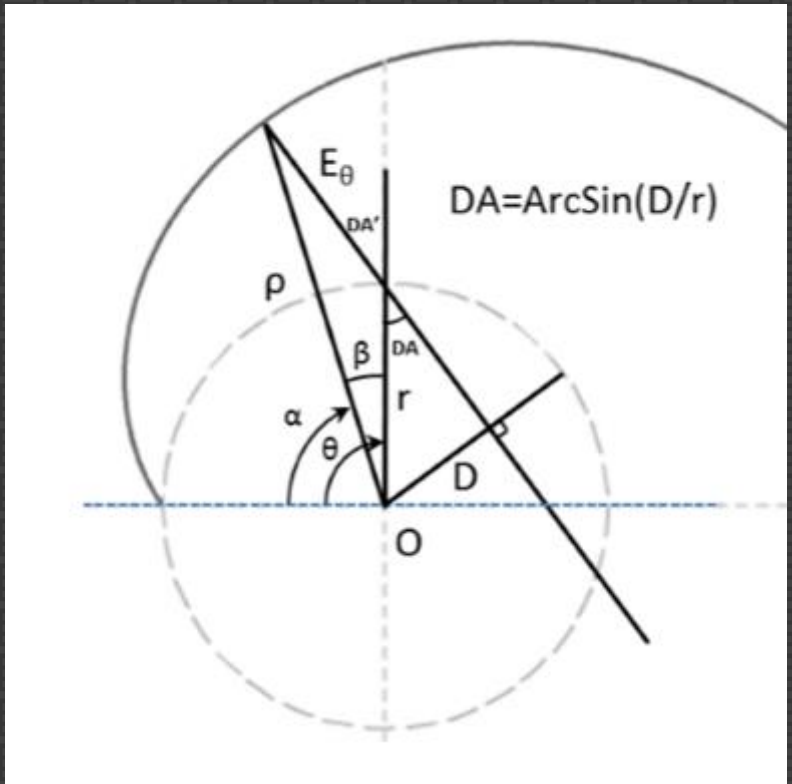


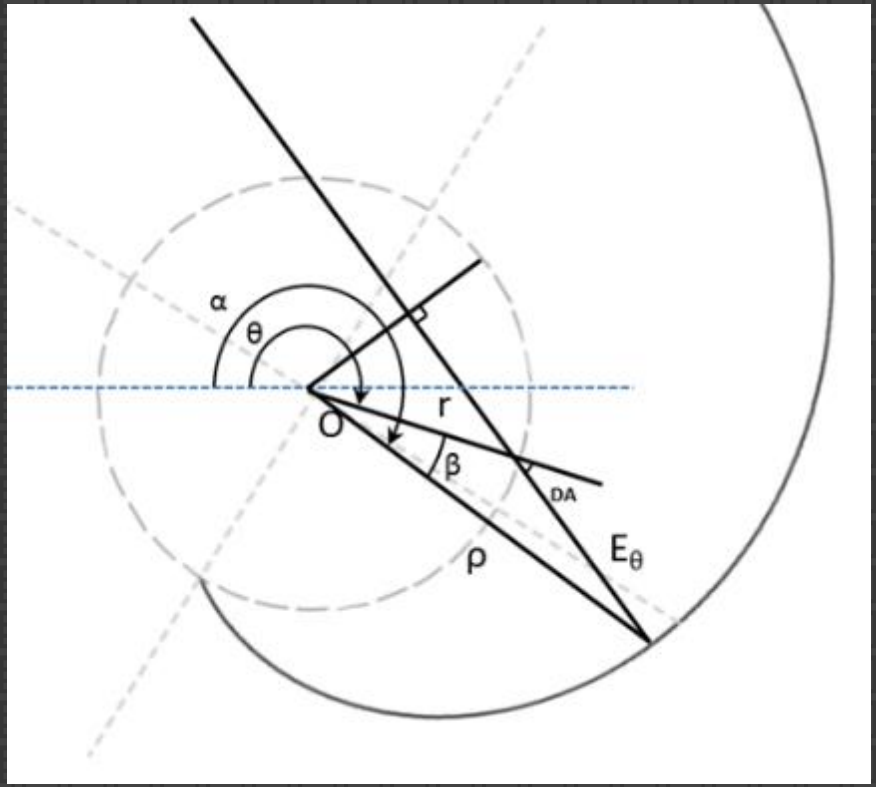
Wind spiral


Adobe Flash Player 34
文件(F) 查看(V) 控制(C) 帮助(H)
速度比
0.8
高度
-40
旋转方向
顺时针
逆时针
运动方向
左到右
右到左
清除
演示
附加设置
起点
正常
近地点
周期
1
Wind Spiral
Sin(DA)=0.8

General formula of Equidistant Spiral

$$\rho = r * \sqrt{(\frac{w}{v})^2\theta^2 + 2(\frac{w}{v})\theta Cos(DA) + 1}$$ （注：$E_\theta = \theta * r * w/v$）





r Radius of the circle
w speed on the line
v speed on the circle
D Distance to the center

equal velocity ratio spiral

$\alpha=\theta-\beta=\theta-\arcsin(E_\theta * \sin DA/\rho)$

$\alpha=\theta+\beta=\theta+\arcsin(E_\theta * \sin DA/\rho)$

Conversion of Equidistant Spiral formula

$$\rho = r * \sqrt{(\frac{w}{v})^2\theta^2 + 2(\frac{w}{v})\theta Cos(DA) + 1} \quad \text{（公式一）}$$

$$\alpha=\theta-\beta=\theta-\arcsin(E_\theta * \sin DA/\rho) \quad \text{（公式二）}$$

$$\alpha=\theta+\beta=\theta+\arcsin(E_\theta * \sin DA/\rho) \quad \text{（公式三）}$$

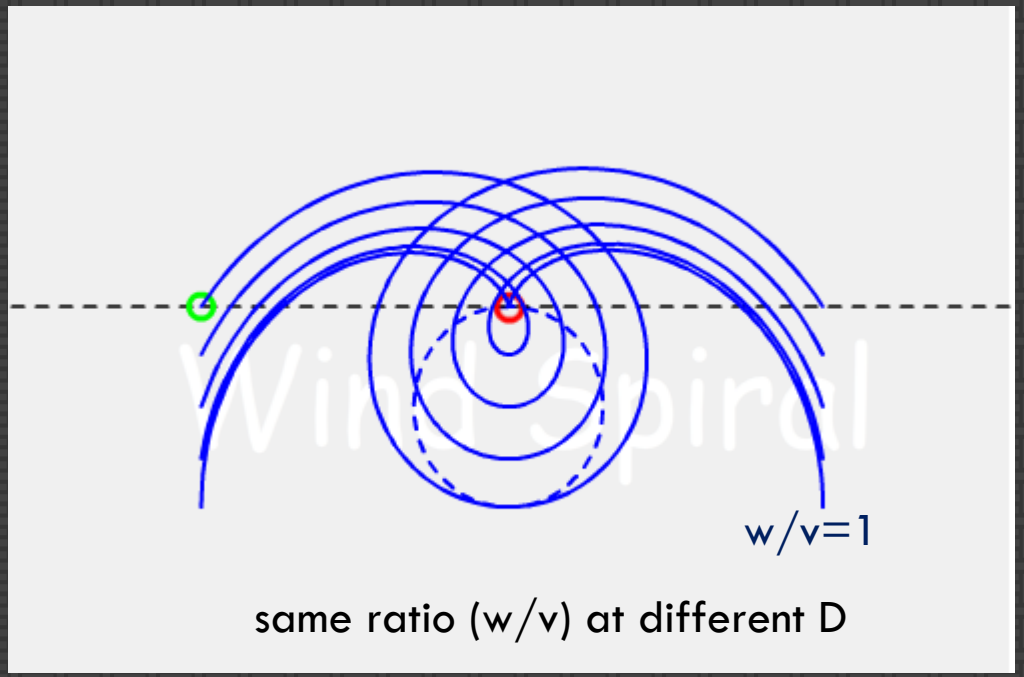
（注：$E_\theta = \theta * r * w/v$）

Circle	Archimedes Spiral	Wind Spiral	Involute curve
w = 0	DA = 0°	DA = arcSin(w/v) or w/v = D/r	DA = 90° w = v
ρ = r α = θ	ρ = r * θ * (w/v) α = θ	ρ = r*... α = θ − β or α = θ + β	ρ = r/cos(β) α = tan(β) − β

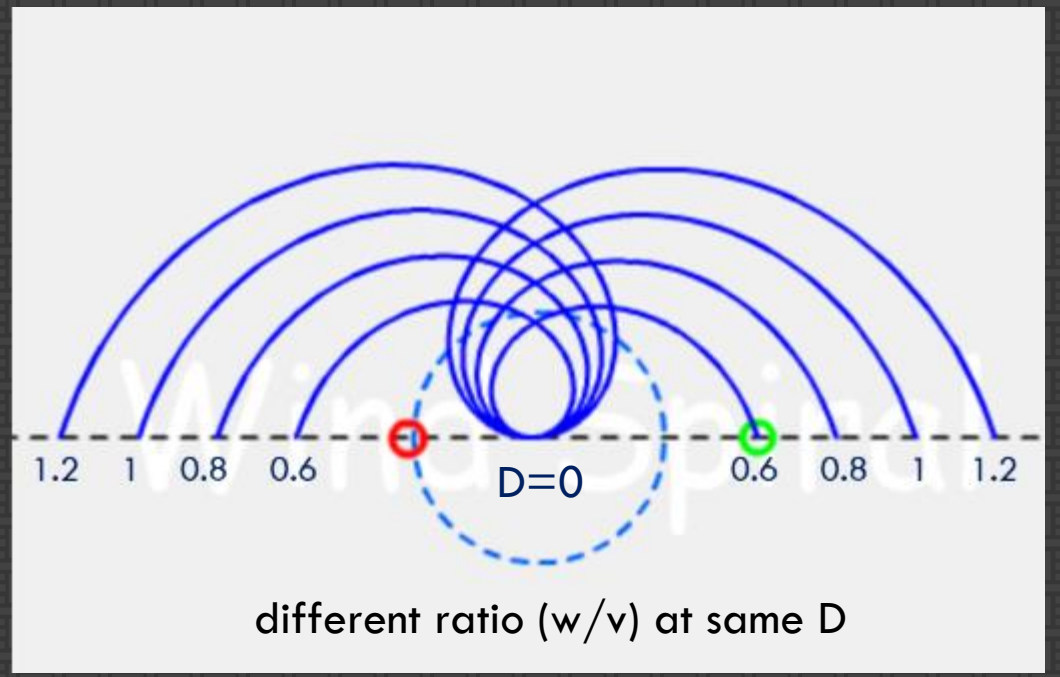
Characteristic of Equidistant Spiral

Basic characteristic

1. In each rotation period expand the same distance.
2. Every Equidistant Spiral has a constant ratio of w/v.



same ratio (w/v) at different D



different ratio (w/v) at same D

Characteristic of Equidistant Spiral

Advanced characteristic

1. Axisymmetric

- The full path of spiral is Axisymmetric figure.

2. Complementary

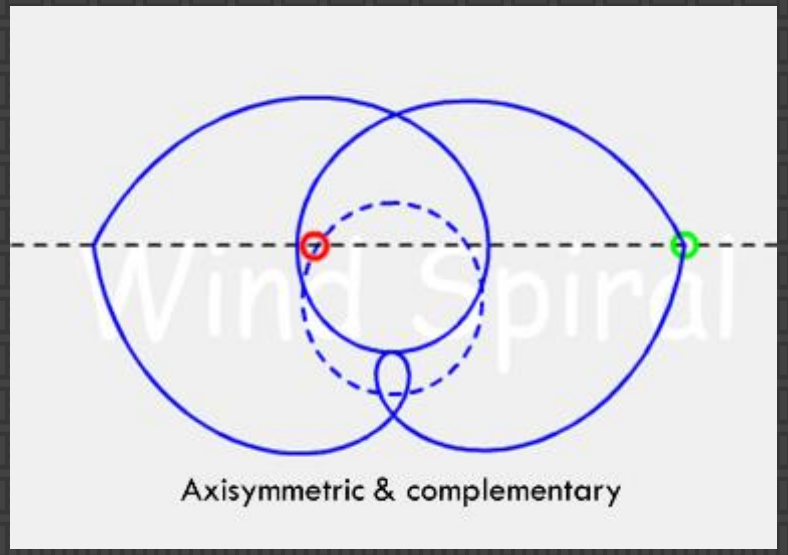
- Spiral with different rotate direction will complementary with each other.

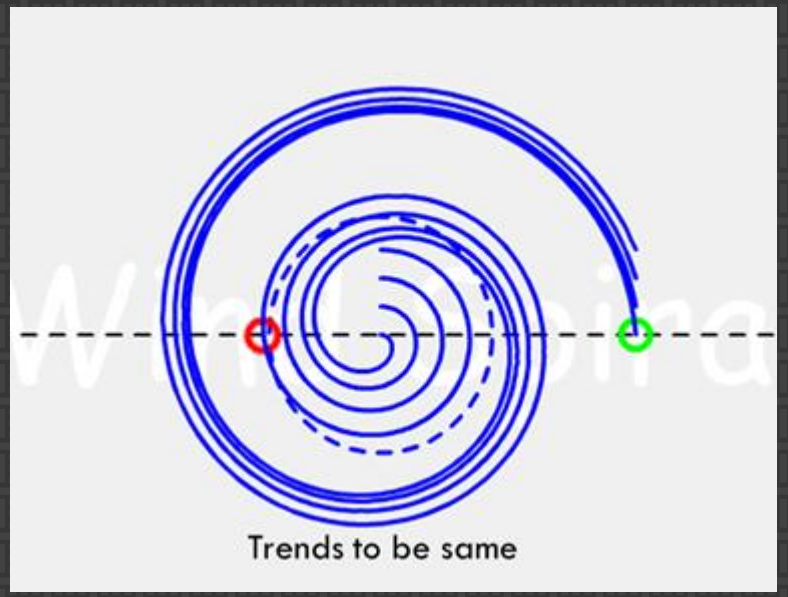
3. Trends to be same

- In a long period all spiral will go the same.

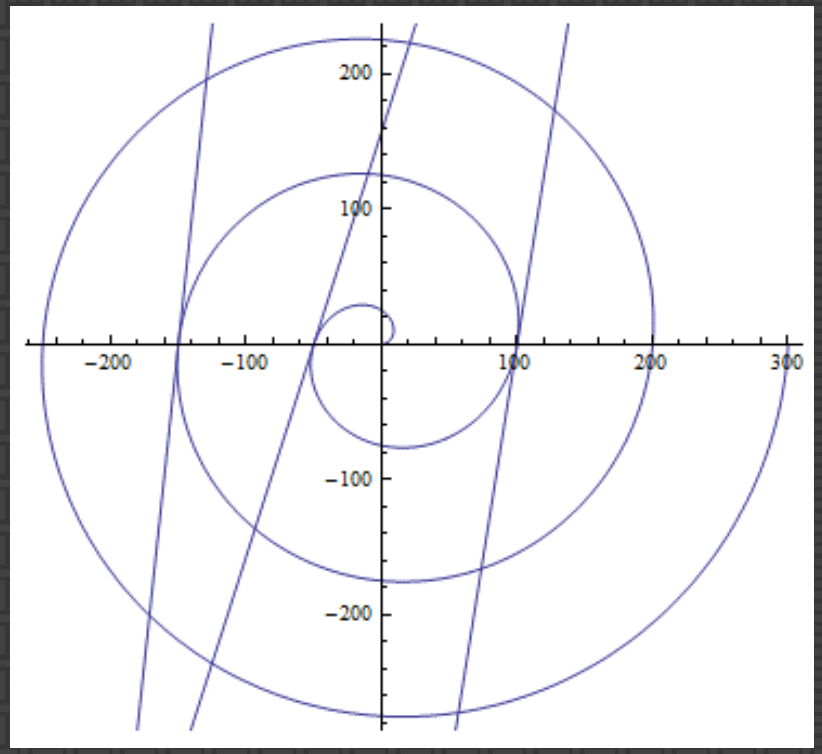
4. Uncertain

- From the track of spiral couldn’t judge the direction of the motion.

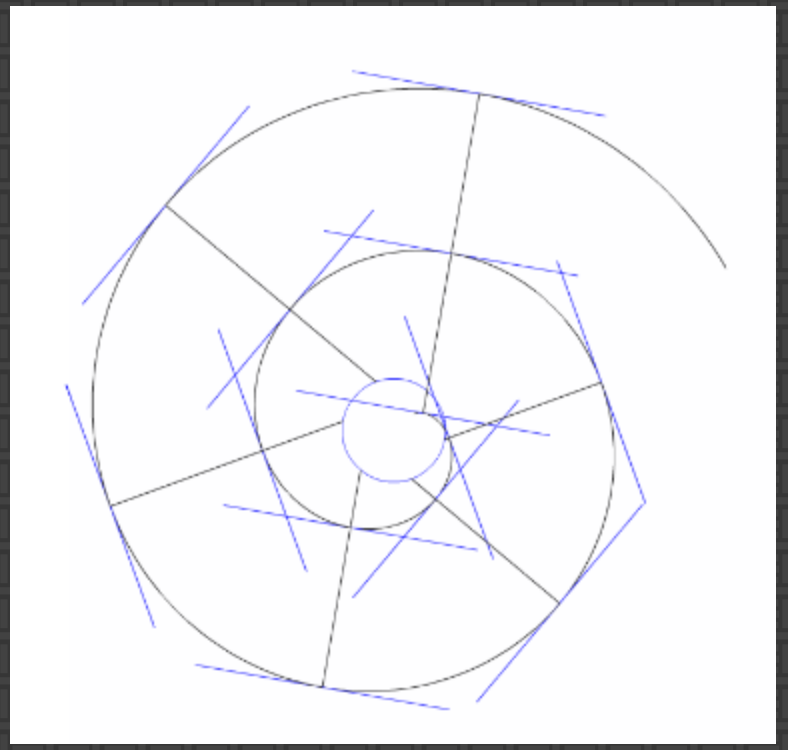




Tangent Line of Wind Spiral



Archimedes helix



Wind Spiral & Involute curve

Part III

Wind Spiral and Flight Procedure Design

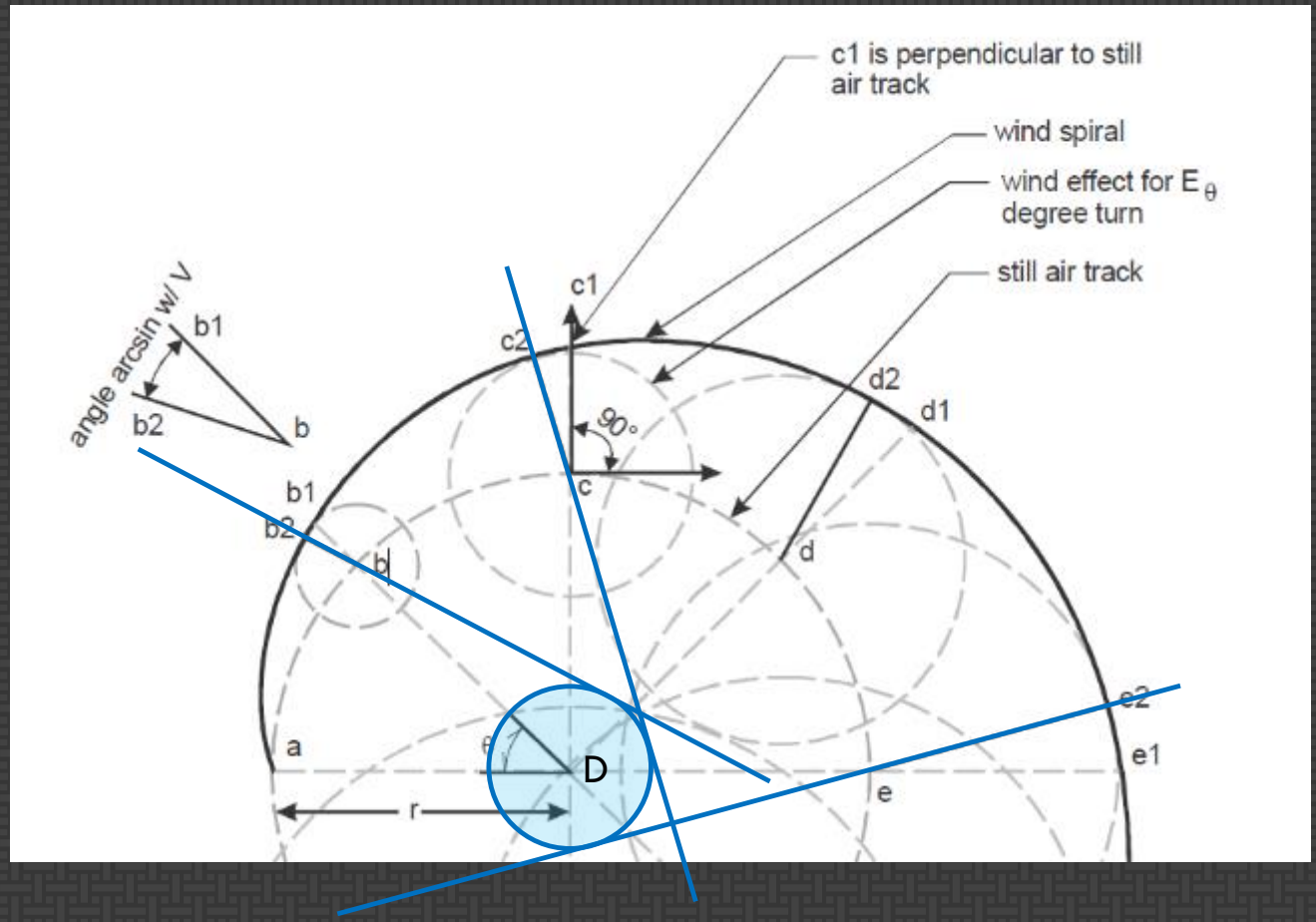
Wind Spiral review

Wind spiral is one kind of

Equidistant Spiral

DA = arcSin(w/v) = arcSin(D/r)

(Default condition: w < v)



Two equivalent drawing methods of wind spiral

1. Using formular

Follow the formular

calculate(α, ρ)

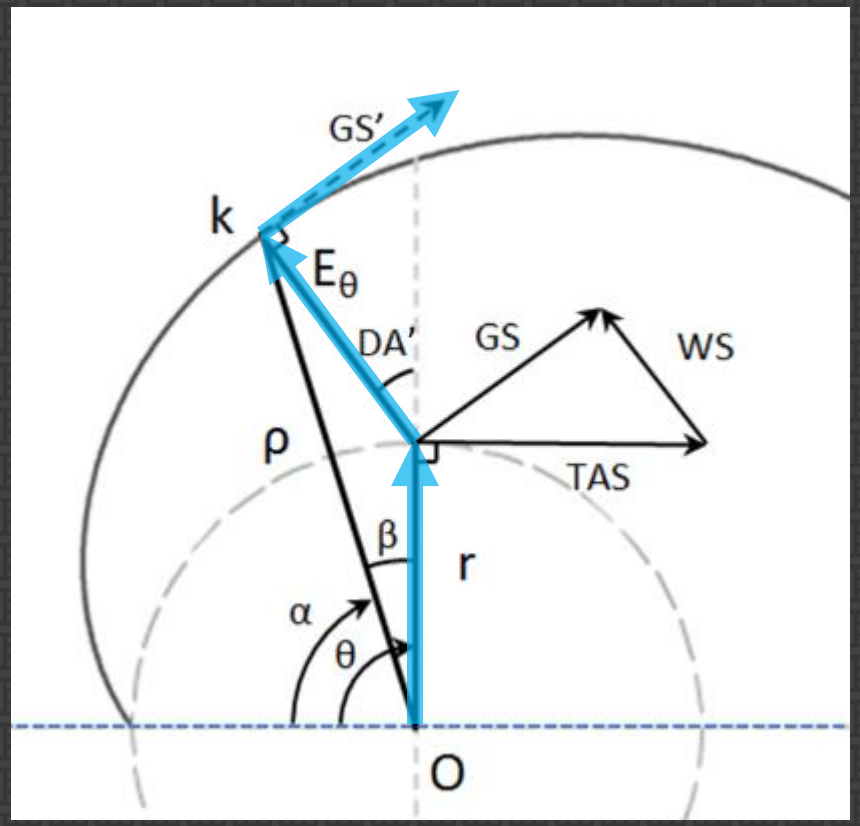
$$E_\theta = \frac{WS}{R} * \theta$$

$$\rho = \sqrt{E_\theta{}^2 + r^2 + 2 * E_\theta * r * \cos(DA')}$$

$$\alpha = \theta - \beta = \theta - \arcsin\left(\frac{E_\theta * \sin(DA')}{\sqrt{E_\theta{}^2 + r^2 + 2 * E_\theta * r * \cos(DA')}}\right)$$

2. Geometric Method

From the center, according to the **θ** draw radius, draw back with DA, draw E**θ** and tangent line.

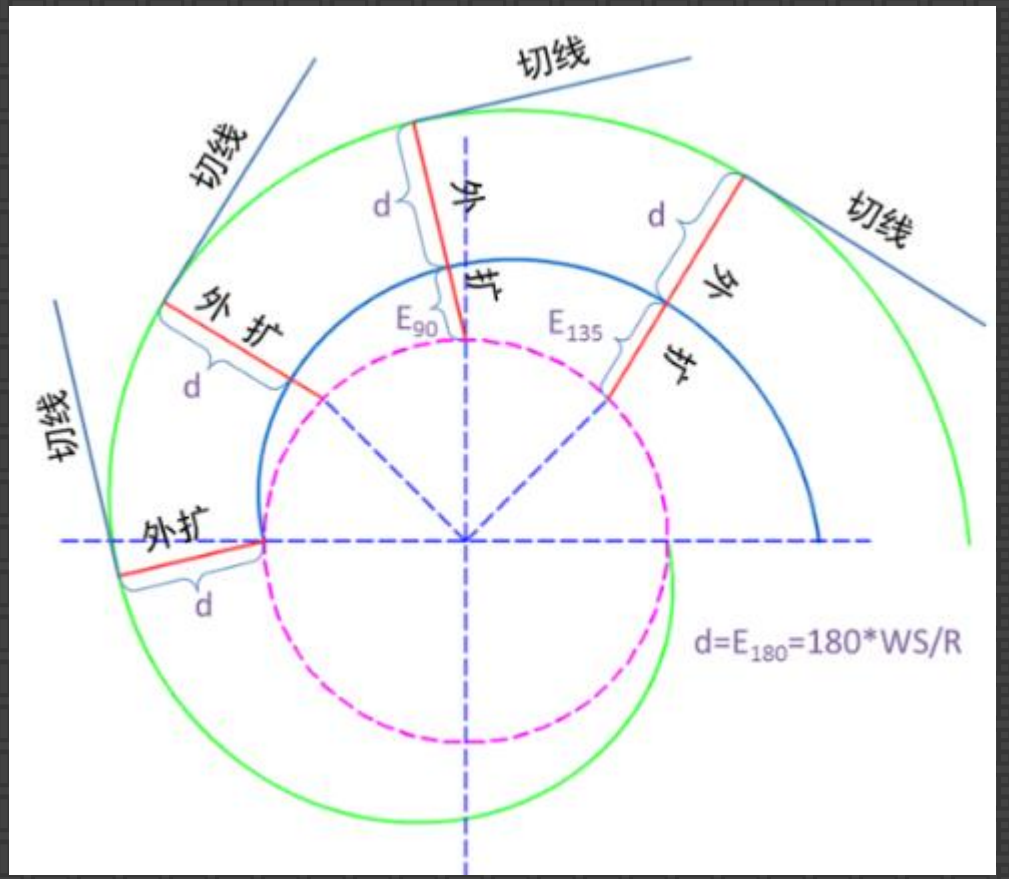


Expand of Wind spiral

$$E\theta=(WS/R)*\theta$$

$$\theta=E\theta/(WS/R)$$

Expand distance could be convert to the angle to be rotated.



Calculate of Tangent Line

Tangent Line perpendicular to the Eθ.

Given Condition:

DA = 15°

Nominal track direction 120°

Question:

θ1 for 15° outword expansion line:

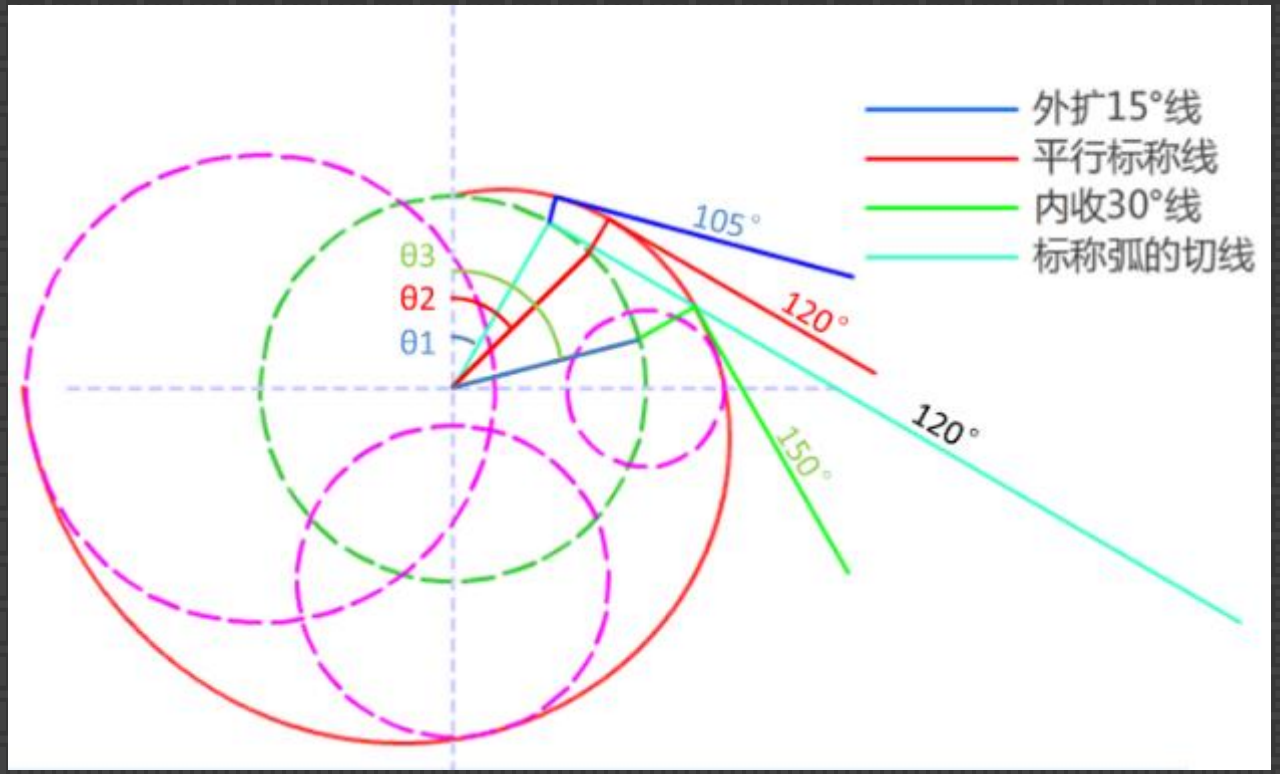
θ1=120-90+DA-15=30°

θ2 for parallel line:

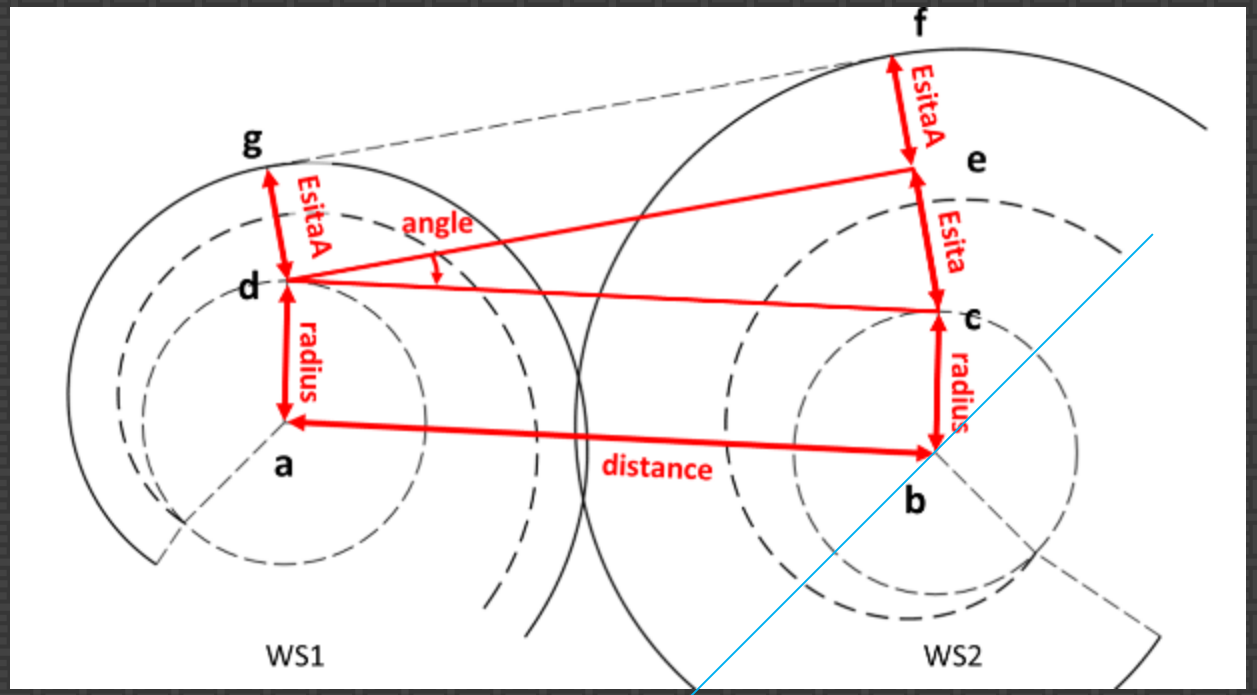
θ2=120-90+DA=45°

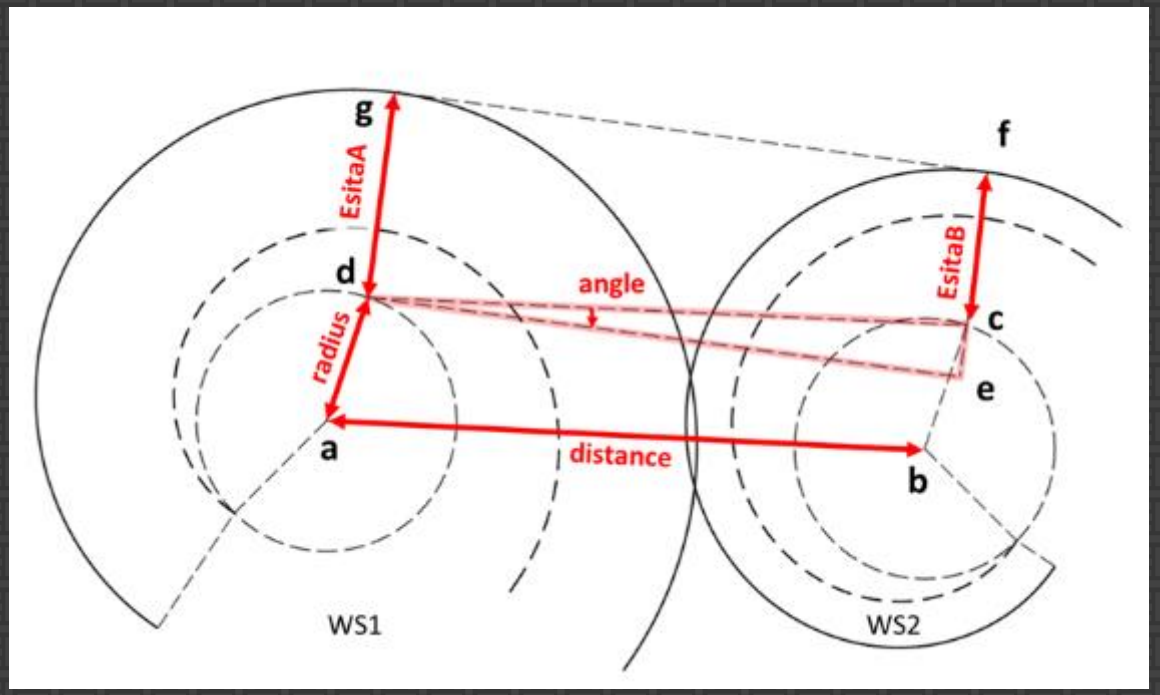
θ3 for 30° inner direction line:

θ3=120-90+DA+30=75°



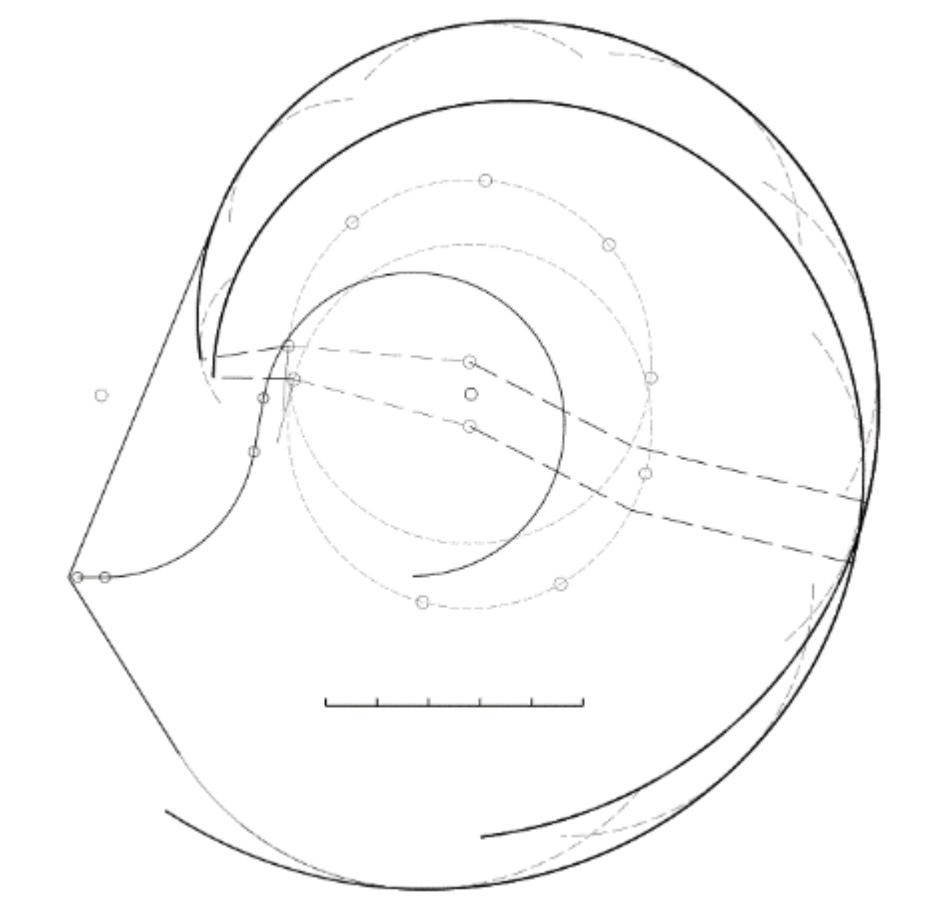
Common Tangent Line of Wind Spiral

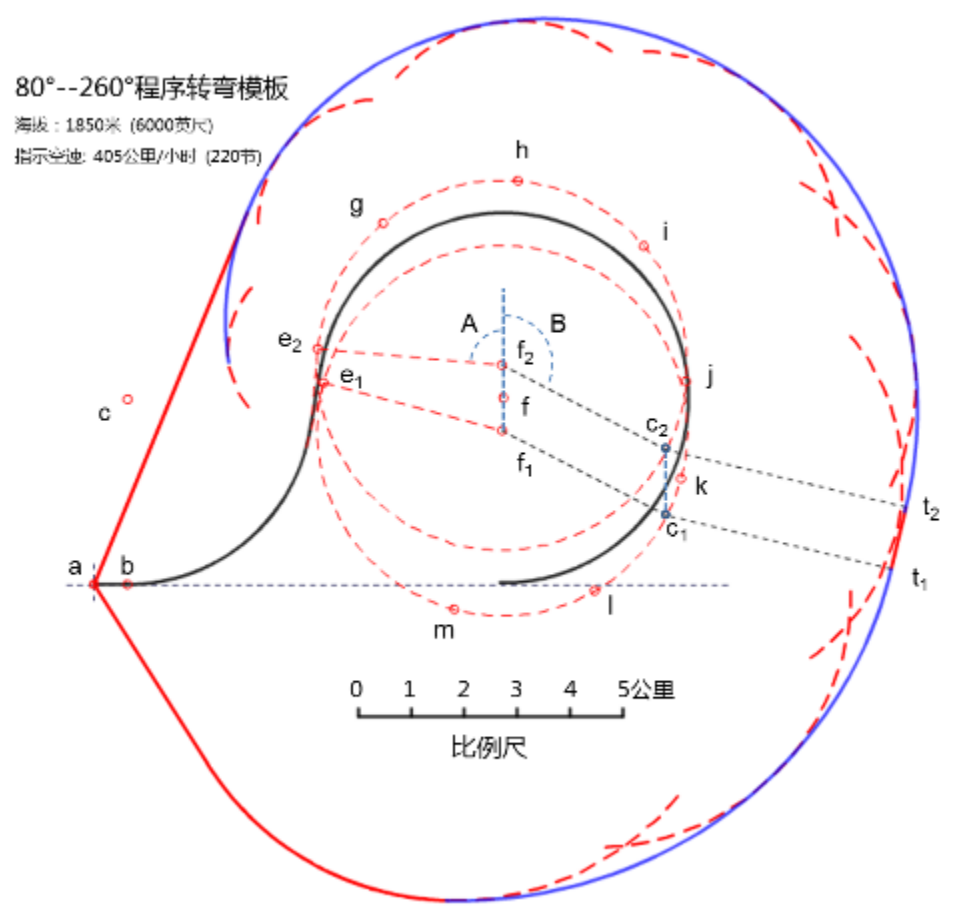




80/260 Procedure Turn Template

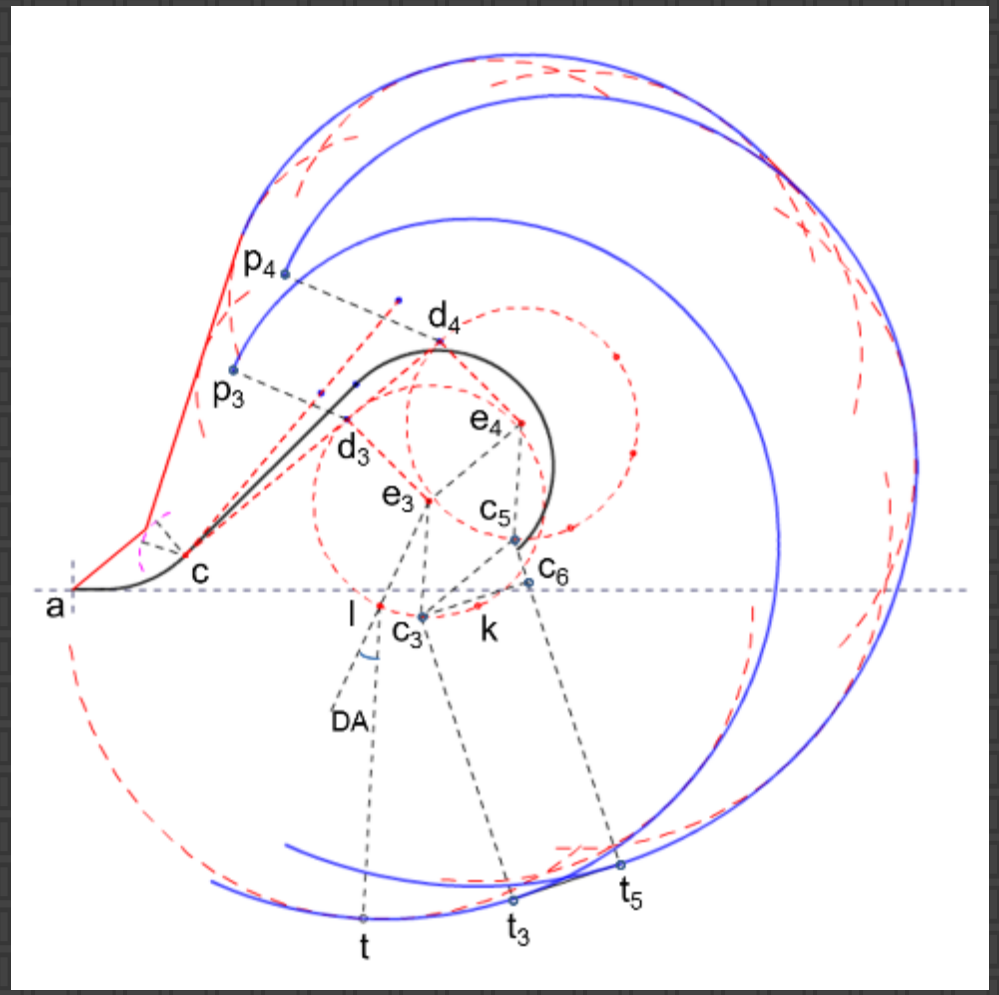
Template defined by Two wind-spiral

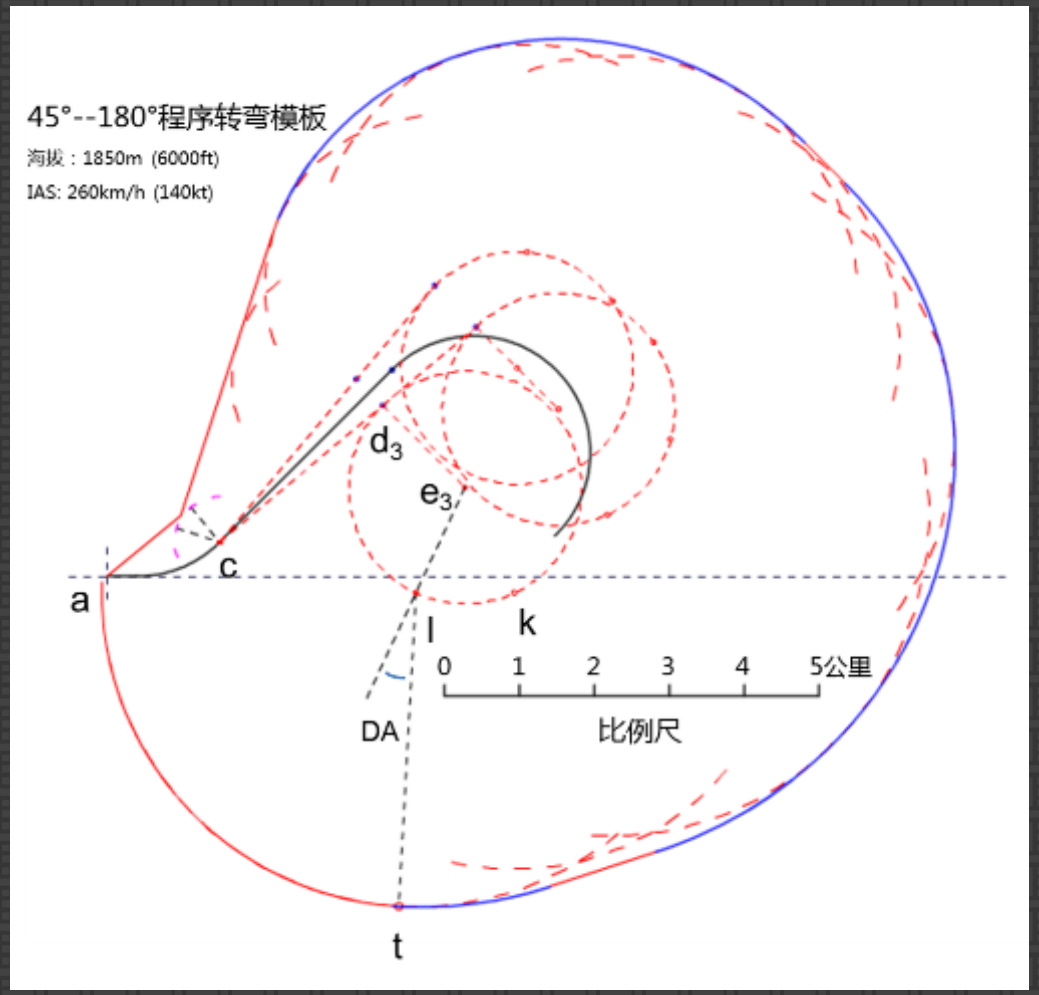




45/180 Procedure Turn Template

Template defined by Three wind-spiral





PBN Flyby turn protection area

Using 2 wind spiral.(Expansion spiral could be see as the inner one)

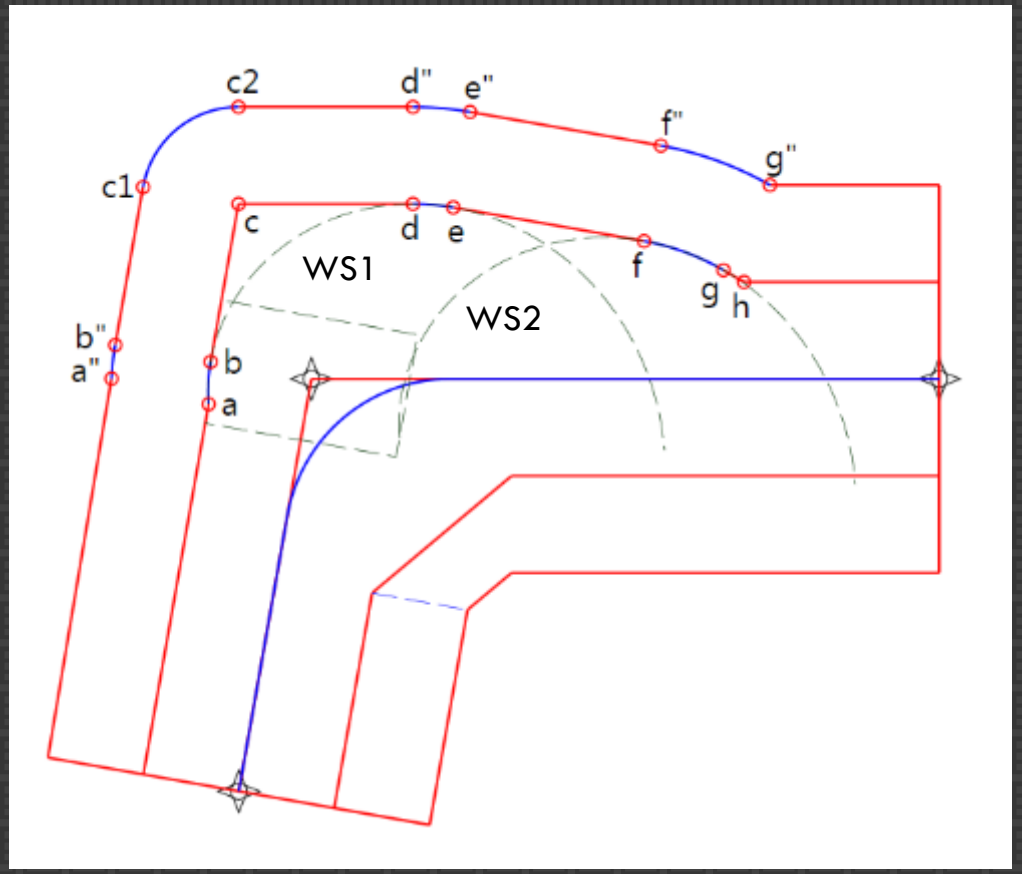


表 1 旁切转弯保护区 θ 角计算表

名称	所属螺旋	作用	θ 角度值
a	ws1	起点	0
a″	ws1 外扩段	起点	递归计算
b	ws1	终点	DA
b″	ws1 外扩段	终点	DA
d	ws1	起点	A+DA
d″	ws1 外扩段	起点	A+DA
e	ws1	终点	90°+DA
e″	ws1 外扩段	终点	90°+DA
f	ws2	起点	90°+DA
f″	ws2 外扩段	起点	90°+DA
g	ws2	终点	A+DA+30°
g″	ws2 外扩段	终点	递归计算

A Heading change in the turn
DA Drift Angle

PBN Flyover turn protection area

Using 3 wind spiral. (Expansion spiral could be see as the inner one)

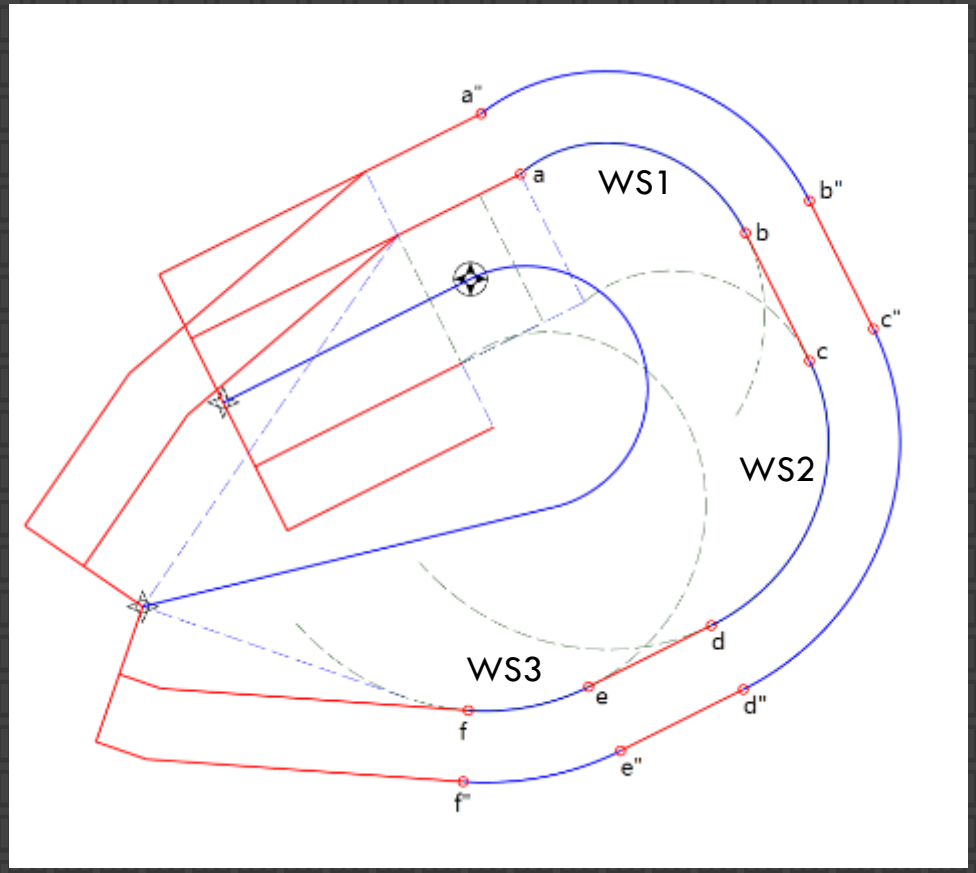
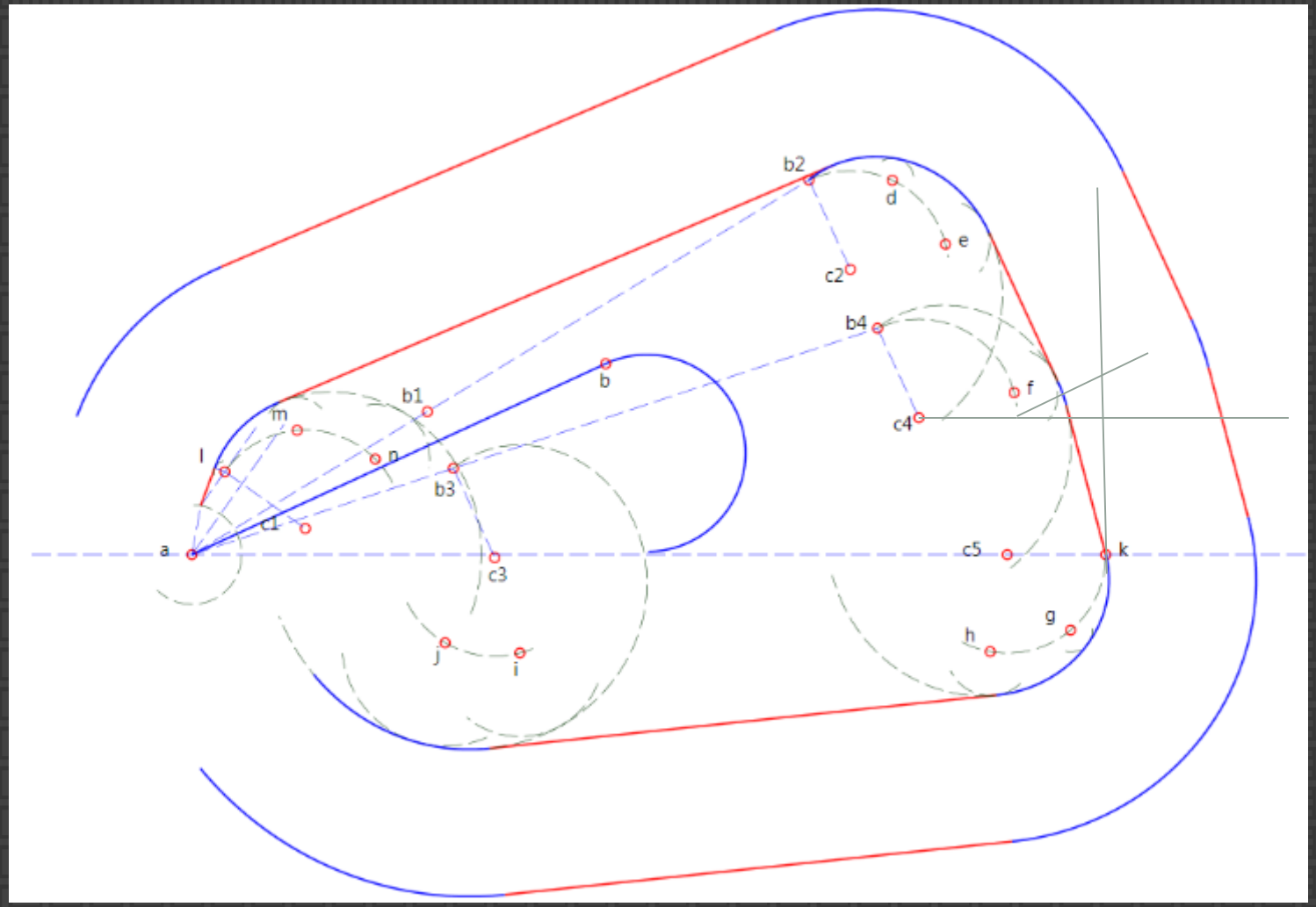


表 1 大角度转弯保护区边界点的 θ 角度值对照表

名称	所属螺旋	作用	θ 角度值
a	ws1	起点	0
a″	ws1 外扩段	起点	递归计算
b	ws1	终点	90+DA
b″	ws1 外扩段	终点	90+DA
c	ws2	起点	90+DA
c″	ws2 外扩段	起点	90+DA
d	ws2	终点	180+DA
d″	ws2 外扩段	终点	180+DA
e	ws3	起点	180+DA
e″	ws3 外扩段	起点	180+DA
f	ws3	终点	递归计算
f″	ws3 外扩段	终点	同 f 点

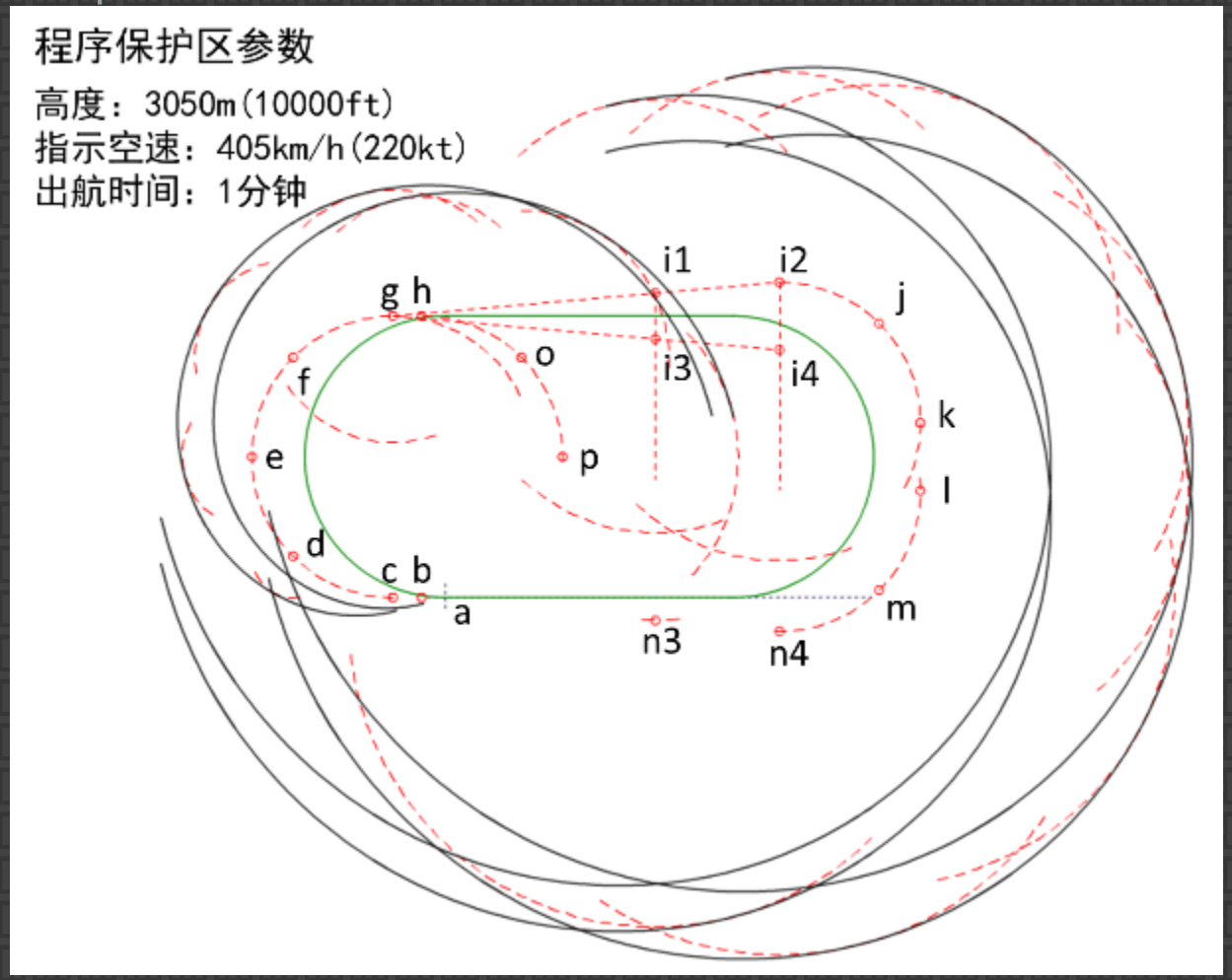
Base turn protection area

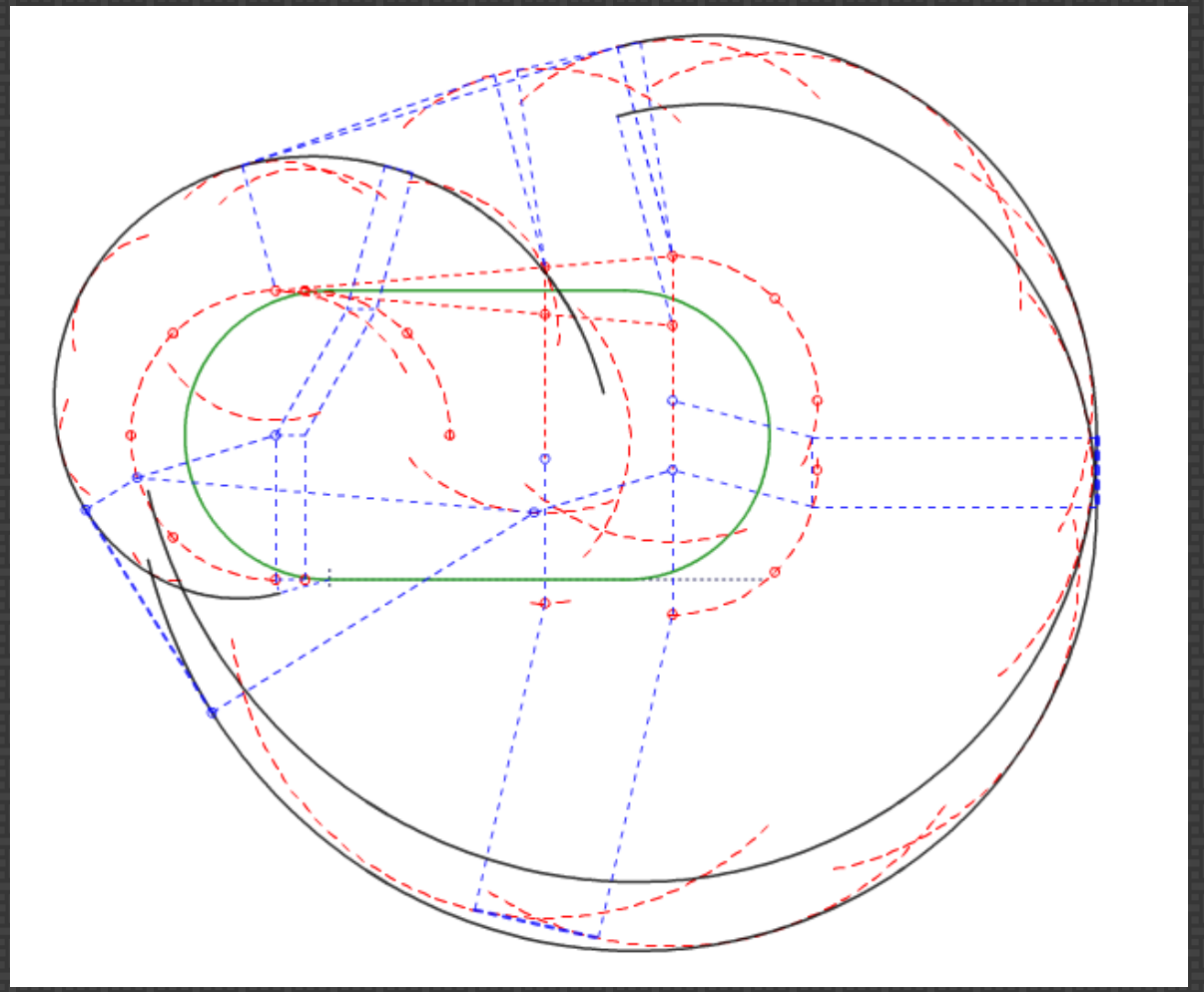
Defined by Four or Five wind spiral.



Basic holding template

Defined by Six wind spiral.





Opportunity for Wind Spiral

1. The concept of Equidistant spiral will change the idea of spiral in many ways.

2. The accurate calculation algorithm for PBN and conventional procedure will greatly promote the standardization of flight procedure design.

3. Wind spiral algorithm will improve the integrity and accuracy of flight procedure.

Challenge for Wind Spiral

1. Need to be widely proved by different country or different agency. to avoid any potential error in it.

2. Need to be authority by ICAO, before it become the formal material in procedure design.

3. The template in Doc9371 need to be checked with this new method.

Web site for related topic.

Thanks

Have a good day!

Wind Spiral

The road for Equidistant