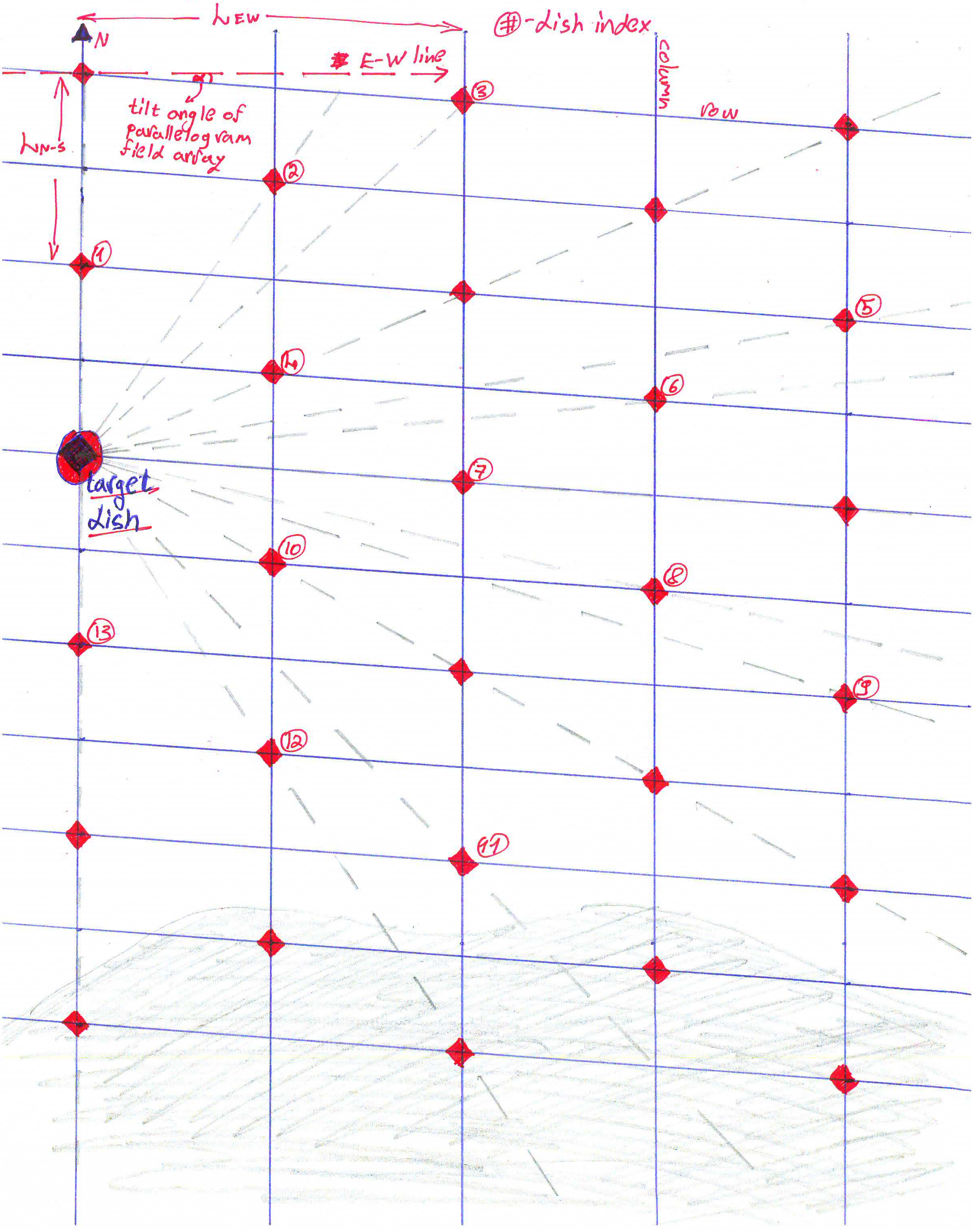
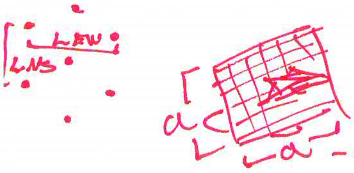
Heliofocus Field Layout - dedicated shading calculation

Dish layout in Heliofocus field:





el - elevation (sun) α - Parallelogram angle from E-W line (cw)
az - azimuth (sun)

a - dish rib length   D - shadow length at elevation axis plane (of dish)

Azto - azimuth angle from north to shading dish, by target dish cycle

Dto - distance from shading dish to target dish

Heliofocus field Shading calculation (Parallelogram array)

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$D = \frac{a}{\sin(el)}$; N-S symetry cycle : 13 effecting dishes

Dishes location relating to shaded dish:

$Dto1 = L_{N-S}$

$Azto1 = 0^\circ$

$Dto2 = \sqrt{[L_{N-S}\cdot 1.5 - L_{E-W}\cdot 0.5\cdot tg(\alpha)]^2 + [L_{E-W}\cdot 0.5]^2}$

$Azto2 = \sin^{-1}\left[\frac{L_{E-W}\cdot 0.5}{Dto2}\right] = tg^{-1}\left[\frac{L_{E-W}\cdot 0.5}{L_{N-S}\cdot 1.5 - L_{E-W}\cdot 0.5\, tg(\alpha)}\right]$

$Dto3 = \sqrt{[L_{N-S}\cdot 2 - L_{E-W}\cdot 1\cdot tg(\alpha)]^2 + [L_{E-W}\cdot 1]^2}$

$Azto3 = \sin^{-1}\left[\frac{L_{E-W}\cdot 1}{Dto3}\right] = tg^{-1}\left[\frac{L_{E-W}\cdot 1}{L_{N-S}\cdot 2 - L_{E-W}\cdot 1\, tg(\alpha)}\right]$

$Dto4 = \sqrt{[L_{N-S}\cdot 0.5 - L_{E-W}\cdot 0.5\cdot tg(\alpha)]^2 + [L_{E-W}\cdot 0.5]^2}$

$Azto4 = \sin^{-1}\left[\frac{L_{E-W}\cdot 0.5}{Dto4}\right] = tg^{-1}\left[\frac{L_{E-W}\cdot 0.5}{L_{N-S}\cdot 0.5 - L_{E-W}\cdot 0.5\cdot tg(\alpha)}\right]$

$Dto5 = \sqrt{[L_{N-S}\cdot 1 - L_{E-W}\cdot 2\cdot tg(\alpha)]^2 + [L_{E-W}\cdot 2]^2}$

$Azto5 = \sin^{-1}\left[\frac{L_{E-W}\cdot 2}{Dto5}\right] = tg^{-1}\left[\frac{L_{E-W}\cdot 2}{L_{N-S}\cdot 1 - L_{E-W}\cdot 2\cdot tg(\alpha)}\right]$

$Dto6 = \sqrt{[L_{N-S}\cdot 0.5 - L_{E-W}\cdot 1.5\cdot tg(\alpha)]^2 + [L_{E-W}\cdot 1.5]^2}$

$Azto6 = \sin^{-1}\left[\frac{L_{E-W}\cdot 1.5}{Dto6}\right] = tg^{-1}\left[\frac{L_{E-W}\cdot 1.5}{L_{N-S}\cdot 0.5 - L_{E-W}\cdot 1.5\cdot tg(\alpha)}\right]$

$Dto7 = \sqrt{[L_{N-S}\cdot 0 - L_{E-W}\cdot 1\cdot tg(\alpha)]^2 + [L_{E-W}\cdot 1]^2} = \frac{L_{E-W}}{\cos(\alpha)}$

$Azto7 = \sin^{-1}\left[\frac{L_{E-W}\cdot 1}{Dto7}\right] = 90^\circ + \alpha = tg^{-1}\left[\frac{L_{E-W}\cdot 1}{L_{N-S}\cdot 0 - L_{E-W}\cdot 1\cdot tg(\alpha)}\right]$

$Dto8 = \sqrt{[-L_{N-S}\cdot 0.5 + L_{E-W}\cdot 1.5\cdot tg(\alpha)]^2 + [L_{E-W}\cdot 1.5]^2}$

$Azto8 = \sin^{-1}\left[\frac{-L_{E-W}\cdot 1.5}{Dto8}\right] = tg^{-1}\left[\frac{L_{E-W}\cdot 1.5}{-L_{N-S}\cdot 0.5 + L_{E-W}\cdot 1.5\cdot tg(\alpha)}\right]$

if $az > 180 \rightarrow az = az - 180$

if $Azto < 0$!!!

$Azto = 180^\circ + Azto$

$$Dto9 = \sqrt{\left[d_{N-S}\cdot 1 + d_{E-W}\cdot 2\cdot tg(\alpha)\right]^2 + \left[d_{E-W}\cdot 2\right]^2}$$

$$Azto9 = \sin^{-1}\left[\frac{d_{E-W}\cdot 2}{Dto9}\right] = tg^{-1}\left[\frac{d_{E-W}\cdot 2}{-d_{N-S}\cdot\cancel{\;} + d_{E-W}\cdot 2\cdot tg(\alpha)}\right]$$

$$Dto10 = \sqrt{\left[-d_{N-S}\cdot 0.5 + d_{E-W}\cdot 0.5\cdot tg(\alpha)\right]^2 + \left[d_{E-W}\cdot 0.5\right]^2}$$

$$Azto10 = \sin^{-1}\left[\frac{d_{E-W}\cdot 0.5}{Dto10}\right] = tg^{-1}\left[\frac{d_{E-W}\cdot 0.5}{-d_{N-S}\cdot 0.5 + d_{EW}\cdot 0.5\cdot tg(\alpha)}\right]$$

$$Dto11 = \sqrt{\left[-d_{N-S}\cdot 2 + d_{EW}\cdot 1\cdot tg(\alpha)\right]^2 + \left[d_{E-W}\cdot 1\right]^2}$$

$$Azto11 = \sin^{-1}\left[\frac{d_{E-W}\cdot 1}{Dto11}\right] = tg^{-1}\left[\frac{d_{E-W}\cdot 1}{-d_{N-S}\cdot 2 + d_{E-W}\cdot 1\cdot tg(\alpha)}\right]$$

$$Dto12 = \sqrt{\left[-d_{N-S}\cdot 1.5 + d_{E-W}\cdot 0.5\cdot tg(\alpha)\right]^2 + \left[d_{E-W}\cdot 0.5\right]^2}$$

$$Azto12 = \sin^{-1}\left[\frac{d_{E-W}\cdot 0.5}{Dto12}\right] = tg^{-1}\left[\frac{d_{E-W}\cdot 0.5}{-d_{N-S}\cdot 1.5 + d_{E-W}\cdot 0.5\cdot tg(\alpha)}\right]$$

$$Dto13 = d_{N-S}$$

$$Azto13 = 180°$$

Shading algorithm: for all dish indexes

i.e. 1-13:

Az_shade(1.... 13)

El_shade(1... 13)

Az_shade_span 1(1... 13)

Az_shade_span 2(1.... 13)

if $|Azto - az| \geq 90° \rightarrow$ Az_shade=0 (no shade)

else: Az_shade $= a - Dto\cdot|\sin(Azto - az)|$

if Az_shad < 0 → (no shade)

Az_shade = 0

El_Shade $= (D - Dto)\cdot\sin(el)$

if El_shade < 0 → (no shade)

El_shade = 0

each shading dish azimuthial/width span on target dish:

if Az_shade > 0

if $sign[\sin(Azto - az)] > 0$ and $|Azto - az| \geq 90°$

Az_shade span 1 $= \frac{a}{2}$

Az_shade_span 2 $= \frac{a}{2}$ − Az_shade

else if $sign[\sin(Azto - az)] < 0$ and $|Azto - az| \geq 90°$

Az_shade_span 1 = Az_shade $- \frac{a}{2}$

Az_shade_span 2 $= -\frac{a}{2}$

else if $sign[\sin(Azto - az)] = 0$ and $|Azto - az| \geq 90°$

Az_shade_span 1 $= a/2$

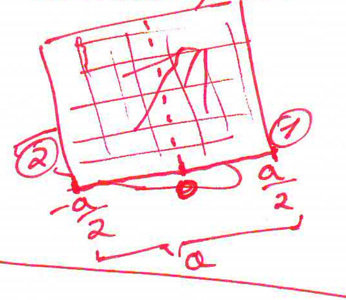
Az_shade_span 2 $= -\frac{a}{2}$

else

Az_shade_span 1 = 0

Az_shade_span 2 = 0

Az_shad_span:



1st order shade overlap/double ocupation

```
if Az_shade.1>0 and Az_shade2>0
    P1=Az_shade_span1.1
    P2=Az_shade_span2.1
    S1=Az_shade_span1.2
    S2=Az_shade_span2.2
    if S1<P2
        S1=P2
        λ=S1-S2
    else if S2<P2
        S2=P1
        λ=S1-S2
    else
        λ=Az_shade.2
Az_shade.2=λ //
```

(example of i=1)

P - first dish shade lines
S - second 1st order dish shade lines
λ - actual shad from second dish (after disregarding overlap)

do this 'scheme' for the rest of the cases:

i - dish index by CW direction from north

i.e.: if Az_shade.i>0 and Az_shade.i+1>0

"scheme"

Az_shade.i+1 = λ //

$\boxed{i = 1....12}$

if Az_shade.i+1<0 -> Az_shade.i+1=0

2nd order shade overlap/double ocupation

```
if Az_shade.1>0 and Az_shade.3>0
    P1=Az_shade_span1.1
    P2=Az_shade_span2.1
    S1=Az_shade_span1.3
    S2=Az_shade_span2.3
    if S1>P2
        S1=P2
        λ=S1-S2
    elseif S2>P2
        S2=P1
        λ=S1-S2
    else
        λ=Az_shade.3
Az_shade.3=λ //
```

(example of [i,j]=[1,3])

P - first dish shade lines
S - second 2nd order dish shade lines
λ - actual shade from 2nd order second dish (after disregarding overlap)

do this 'scheme' for:

i dish index of closer dish
j dish index of further dish

i	j
1	3
4	2
4	6
7	5
7	9
10	8
10	12
13	11

case as such:

if Az_shade.i and Az_shade.j

"scheme"

Az_shade.j = λ //

if Az_shade.j<0 -> Az_shade.j=0

avarage shading with respect to exterior rows (first and second from field boundary):

N_{N-S} - number of dishes in column ; N_{E-W} - number of dishes in a row

$\boxed{\begin{array}{l}\text{outer\_rim - shaded area at outer field row} \\ \text{secondary\_rim - shaded area at one row in from}\end{array}}$

if $0° \leq az < 90°$ or $180° \leq az < 270°$

$$outer\_rim = (N_{N-S}-1) \cdot (Az\_shade.1 \cdot El\_shad.1) + (N_{EW}-1) \cdot (Az\_shade.7 \cdot El\_shade.7)$$

$$secondary\_rim = \left[(N_{N-S}-2) + (N_{E-W}-2)\right] \cdot Az\_shade.4 \cdot El\_shade.4$$

else

$$outer\_rim = (N_{N-S}-1) \cdot (Az\_shade.13 \cdot El\_shade.13) + (N_{E-W}-1)(Az\_shade.7 \cdot El.shade.7)$$

$$secondary\_rim = \left[(N_{N-S}-2) + (N_{E-W}-2)\right] \cdot Az\_shade.10 \cdot El\_shade.10$$

(i - dish index)

$$dish\_inner\_shade = \sum_{i=1}^{13} Az\_shade.i \times EL\_shade.i$$ (inner field dish shaded area)

$$inner\_shade = (N_{N-S}-2) \cdot (N_{E-W}-2) \cdot dish\_inner\_shade$$ (inner field shaded area)

$$whole\_field\_shaded\_area = inner\_shade + secondary\_rim + outer\_rim$$

$$shading\_percent = \frac{whole\_field\_shaded\_area}{\underbrace{a^2 \cdot N_{EW} \cdot N_{N-S}}_{\text{total field aperture area}}}$$