

1999

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1999. 12. 31.

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	()
:	()
	()
	()

1.

21

·
·
(GSO) Ku
Ka SkyBridge, Teledesic
(NGSO)
, NGSO
(FSS) GSO (FSS),
(BSS)
가 가
, 가 WRC- 2000
ITU- R SG(Study Group)4 가
·
1995 8 1996 1
· 1 2
Ku · 1999
8 Ku Ka 3
31 74

GSO FSS, BSS

NGSO FSS

가 .

NGSO FSS

GSO FSS, BSS

EPFD(Equivalent

Power Flux Density) mask

ITU-R

JTG 4-9-11

.

NGSO

GSO

.

2.

EPFD	
가.	o NGSO
	o GSO
· PFD/EIRP mask	o PFD mask
	o EIRP mask
· EPFD	o ITU-R JT G 4-9-11/258, 313
	o , Curve fitting
	o EPFD, , EPFD

가. NGSO	<ul style="list-style-type: none"> o ITU-R JTG 4-9-11/325, 367 o <ul style="list-style-type: none"> - - GSO - NGSO o <ul style="list-style-type: none"> - GSO (FSS, BSS) - GSO - NGSO o NGSO o NGSO station keeping . o Time Simulation o EPFD <ul style="list-style-type: none"> - NGSO PFD mask - off-axis - GSO EPFD o EPFD <ul style="list-style-type: none"> - NGSO EIRP mask - off-axis - GSO EPFD o <ul style="list-style-type: none"> - EPFD CDF - EPFD

3.

가. GSO EPFD

. GSO EPFD

. EPFD
ITU-R (S22) EPFD

4.

가. NGSO FSS ,
GSO FSS, BSS

. EPFD mask ITU-R JTG 4-9-11

.
. NGSO NGSO GSO
GSO

5.

가.

. Ku

Ka

GSO

가

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SUMMARY

1. Objective and Necessity

The developed nations put a great effort to acquire limited sources of satellite communications and broadcasting such as frequency spectra and satellite orbits, and to develop the state of art satellite communications and broadcasting technologies. Especially, communication services using NGSO such as SkyBridge, Teledesic in Ku-band and Ka band in which only GSO was used before, is being studied and it will be commonly used soon. The study in interference evaluation method and interference approval criteria should be studied urgently because these satellite systems for NGSO fixed satellite service(FSS) share the frequency band which is distributed the existing GSO FSS, broadcast satellite service(BSS). The study in this issue was adopted as subject for discussion in WRC-2000 and it has been step up actively by ITU-R SG(Study Group)4.

In the domestic by launching the first commercial, communication and broadcasting complex satellites, KOREASAT-1 and KOREASAT-2, in Oct. 1995 and Jan. 1996, space communication and broadcasting times using Ku band were begun. The KOREASAT-3 and a multipurpose practical satellite in Ku and Ka band were launched on 25th

Aug. in 1999. And then we have requested the authority to use 31 Geostationary orbits and 74 frequency bands to the relevant international agency, but the concrete plan to use is not sufficient. Therefore, for the purpose of efficient using these resources of frequency and satellite orbit, it is essential to analyze of the interference to GSO FSS and BSS satellite systems from NGSO FSS satellite system operated in the same frequency band in Korea.

In the research, to analyze the interference to GSO FSS and BSS satellite systems from NGSO FSS satellite system,. we have studied an algorithm to draw a EPFD mask and parameters for analysis of interference and the algorithm presented in ITU-R JTG 4-9-11. we also have developed the program for a analysis of the interference, which can be utilized in driving efficient acquisition and arrangement planning of limited frequency spectra and satellite orbit resources.

2. Contents and Scope of R&D

Satellite interference parameter and EPFD	
Contents	Scope
A. Analysis of satellite interference parameters	<ul style="list-style-type: none">o Analysis of NGSO satellite system parameterso Analysis of standard GSO satellite system parameters
B. Study on PFD/EIRP mask generation algorithm	<ul style="list-style-type: none">o Study of PFD mask generation algorithm of satelliteo Study of EIRP mask generation algorithm of Earth station
C. Study on continuous curve implementation of EPFD	<ul style="list-style-type: none">o Study of documents ITU-R JTG 4-9-11/258, 313o Study of Interpolation, Curve fitting methodo Study of relation among EPFD, antenna diameter and percentage of time during which EPFD level may be exceeded.

Algorithm for interference analysis and program implementation	
Contents	Scope
A. Study of algorithm for interference analysis of NGSO satellite systems	<ul style="list-style-type: none"> o Analysis of ITU-R JTG 4-9-11/325, 367 o Vector representation algorithm of satellite system coordinates o Analysis of antenna gain pattern o Analysis of estimation algorithm for NGSO satellite orbits o Analysis of station keeping algorithm for NGSO satellite orbits
B. Implementation of interference analysis program	<ul style="list-style-type: none"> o Time Simulation method o Down-link EPFD operating process <ul style="list-style-type: none"> - PFD mask analysis by NGSO satellites - Antenna off-axis gain analysis - Total EPFD process of GSO earth station o Up-link EPFD operating process <ul style="list-style-type: none"> - EIRP mask analysis by NGSO earth station - Antenna off-axis gain analysis - Total EPFD process of GSO satellite o Interference discrimination process <ul style="list-style-type: none"> - Algorithm yielding CDF of EPFD - Interference discrimination by time percentage during which EPFD level may be exceeded

3. Results

- Calculation of total EPFD at GSO earth station and implementation of program which performs interference discrimination by time percentage during which EPFD level may be exceeded in downlink using Time simulation method.
- Calculation of total EPFD at GSO space segment and implementation of program which performs interference discrimination by time percentage during which EPFD level may be exceeded in uplink using Time simulation method.
- Calculation of EPFD statistics and limit compliance check using the developed program.

4. Expected Effect and Utilization

A. Expected Effect

- Possibility to provide developed software for domestic satellite communication service provider.
- Preparation for foundation of eliminating possibility of interference among nations by proposing adaptive plans to use domestic satellite network in Ku band and Ka band.

B. Utilization

- Analysis of interference between GSO FSS, BSS which are being used and will be used with NGSO FSS satellite network.
- Protection of the existing domestic GSO satellite network by investigating the effect of NGSO satellite network service.
- Arrangement and planning of frequency spectra and satellite orbit resources.

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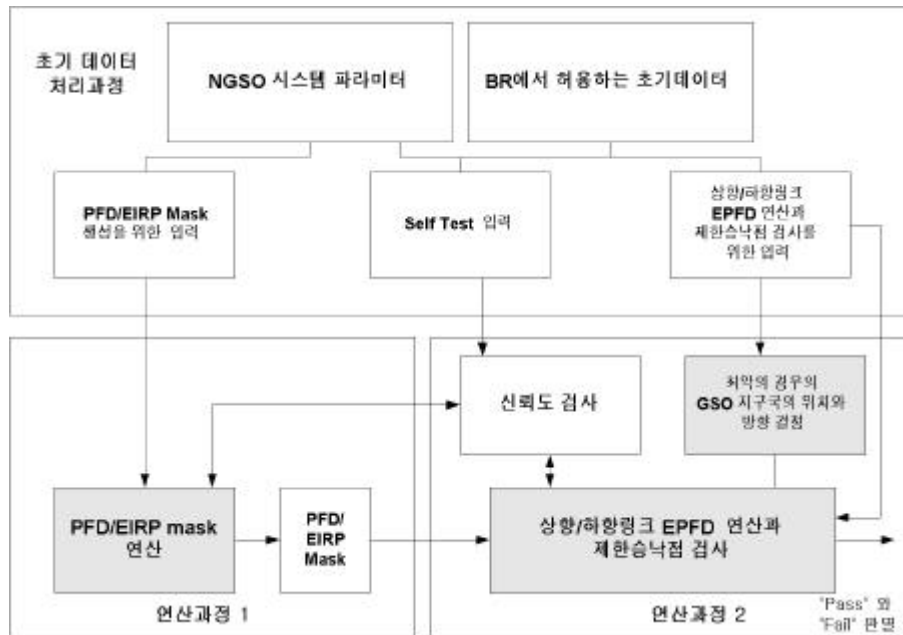
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1

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, 가
가 .
,
(NGSO : Non
Geostationary Satellite Orbit)
. 1990 ,
, NGSO
. NGSO (FSS)
GSO (FSS), (BSS)
가
가
가 WRC- 2000 ITU- R SG(Study
Group) 4 가 .
ITU- R S22 EPFD
NGSO/FSS GSO/FSS ITU- R JT G[I]
, 가 . ,
F- SAT
MULTI 1B[2]
.

2

1 S/W



< 2.1>

(NGSO)

(GSO)

< 2.1>

.

1.

BR (Radiocommunication Bureau)
NGSO

가. BR

BR/ITU

< 2.1> Region

SB	EPFD Bin size (0.1dB)
REGION1_UP	Region 1 (yes or no)
REGION1_DOWN	Region 1 (yes or no)
REGION2_UP	Region 2 (yes or no)
REGION2_DOWN	Region 2 (yes or no)
REGION3_UP	Region 3 (yes or no)
REGION3_DOWN	Region 3 (yes or no)

< 2.2> EPFD

REFBW	EPFD [kHz]
NEPFD_DOWN	EPFD(down)
EPFD_DOWN[I]	NEPFD_DOWN [dBW/m2]
PC[I]	NEPFD_DOWN [%]
EPFD limits	EPFD
RAFBW	EPFD [kHz]
NEPFD_UP	EPFD(up)
EPFD_UP[I]	NEPFD_UP [dBW/m2]
UP_PC[I]	NEPFD_UP [%]

< 2.3>

F_DOWN_{sat}	[GHz]
N_{freq}	region
GSO_SEPARATION	GSO [1 degree]
GSO_LONG	GSO [degrees]
GSO_ES_LAT	GSO [degrees]
GSO_ES_LONG	GSO [degrees]
GSO_ES_PATTERN	GSO
GSO_ES_D_ANT	
BS_LAT	GSO boresight
BS_LONG	GSO boresight
ES_F	[GHz]
GSO_SAT_PATTERN	GSO
GSO_SAT_PEAKGAIN	GSO
GSO_SAT_BEAMWIDTH	GSO
EPFD_{up} limits	EPFD _{up}
PHISTEPCG	coarse time step step [degrees]
THETASTEPCG	coarse time step step [degrees]
PHISTEPFG	fine time step step [degrees]
THETASTEFG	fine time step step [degrees]

. NGSO

< 2.4> NGSO

Nsat	NGSO
Nco[latitude]	NGSO
A[N]	semi- major axis [km]
E[N]	
I[N]	[degrees]
O[N]	[degrees]
W[N]	[degrees]
V[N]	[degrees]
Wdelta	(station keeping)
H_MIN	[km]
ORBIT_PRECESS	precession rate

< 2.5> NGSO

non_GSO_ES_PATTERN	NGSO
P	NGSO [dBW]
FSTART_UP	[GHz]
FEND_UP	[GHz]
REGION1_UP	region 1
REGION2_UP	region 2
REGION3_UP	region 3
ES_TRACK	NGSO
ES_EIRP	RAFBW NGSO EIRP [dBW]
ES_MINELEV	NGSO [degrees]
ES_MIN_GSO	GSO arc [degrees]
ES_DENSITY	km2 NGSO
ES_DISTANCE	cell beam footprint center [km]

< 2.6> NGSO

FSTART_DOWN	[GHz]
FEND_DOWN	[GHz]
REGION1_DOWN	region 1
REGION2_DOWN	region 2
REGION3_DOWN	region 3
Pi	NGSO i [dBW]
G	NGSO [dBi]
G_cross	NGSO [dBi]
Nco	
N	

2.

NGSO / EPFD
· , NGSO APFD가 /
PFD/EIRP mask , NGSO
EPFD .

< 2.7> GSO

GSO_ES_PATTERN	GSO
GSO_SAT_PATTERN	GSO

< 2.8> NGSO PFD mask

MIN_EXCLUDE	Exclusion Zone
option (1) PFD_mask (satellite, latitude, (X), L)	PFD mask - satellite : NGSO - latitude : NGSO sub-satellite point - : NGSO GSO arc - L : NGSO sub-satellite point GSO arc
option (2) PFD_mask (satellite, latitude, AZ, EL)	PFD mask - satellite : NGSO - latitude : NGSO sub-satellite point - AZ : - EL :

< 2.9> NGSO PFD mask

NAPFD	APFD point
APFD[I]	NAPFD APFD [dBW/m ²]
[A]PC[I]	NAPFD
Mitigation Technique	Mitigation

< 2.10> PFD limit

EPFD_{up} limits	EPFD _{up}
EPFD limits	EPFD

2 S/W

Time Simulation time step

NGSO

가 Δt_{ref} . ,
 Δt_{ref} 가 가
 가 Δt_{ref} 가 가 가
 가 .

1. 가

, NGSO GSO
 (In-line situation)

가 Δt_{ref} (2.1) .

$$\Delta t_{ref} = \frac{\Delta t}{N_{hit}} \quad (2.1)$$

, Δt NGSO GSO
 가

.

$$\Delta t = \frac{2\varphi}{w} \quad (2.2)$$

,

$$\varphi = \frac{1}{2} \varphi_{3dB} - \arcsin \left[\frac{R_e}{R_e + h} \sin \left(\frac{1}{2} \varphi_{3dB} \right) \right] \quad (2.3)$$

$$\omega = \sqrt{(\omega_s \cos(i) - \omega_e)^2 + (\omega_s \sin(i))^2} \quad (2.4)$$

$$\omega_s = \frac{0.071}{[(R_e + h)/R_e]^{1.5}} \quad (2.5)$$

$$N_{hit} : \Delta t \quad \text{EPFD} \quad (\geq 5)$$

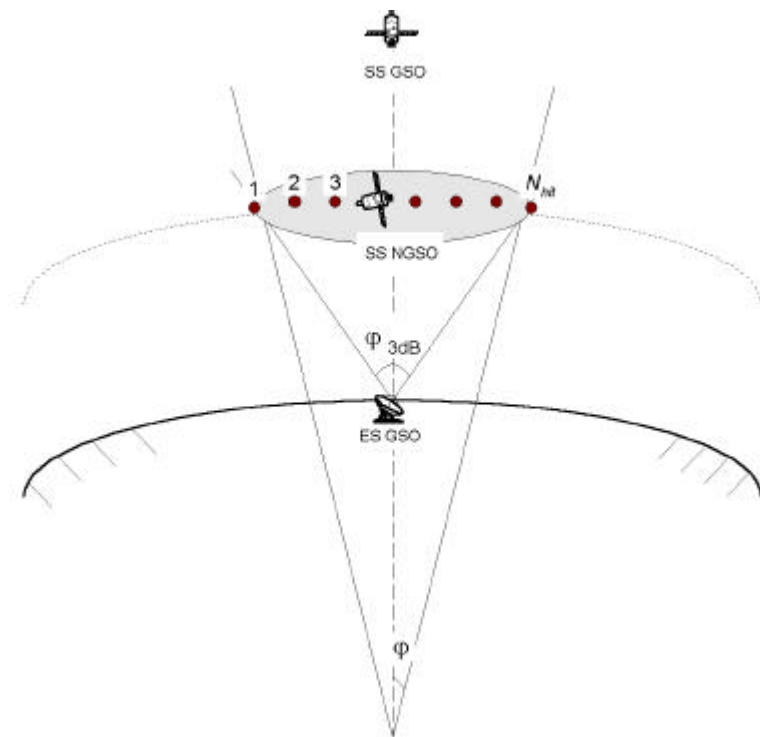
$$w_s : \text{NGSO} \quad [\text{degrees/sec}]$$

$$w_e : \quad [\text{degrees/sec}]$$

$$i : \quad [\text{degrees/sec}]$$

$$\varphi_{3dB} : \text{GSO} \quad 3\text{dB} \quad [\text{degrees}]$$

$$R_e : \quad [\text{km}]$$



< 2.2>

< 2.2> in-line event

NGSO

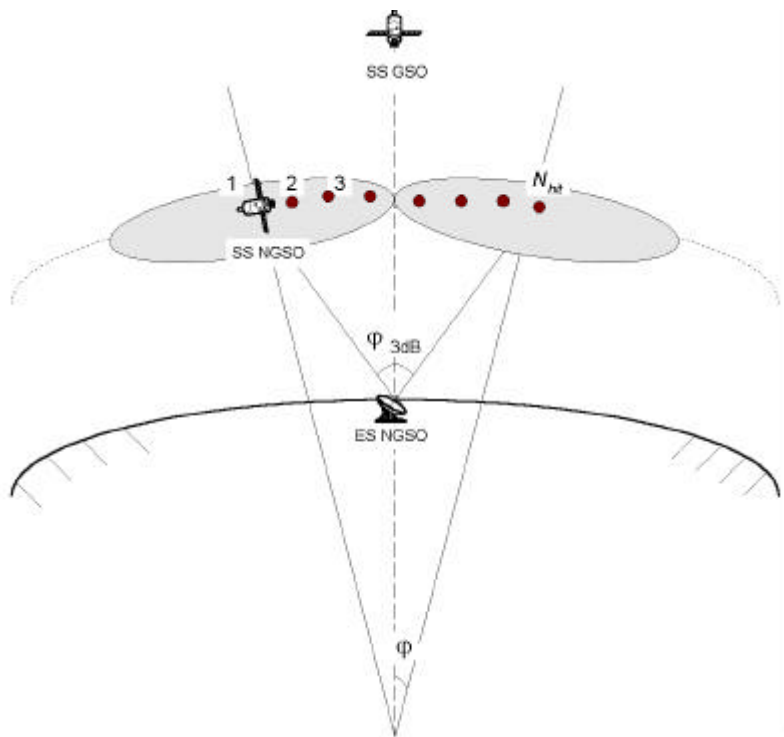
, NGSO GSO

3dB

.

2. 가

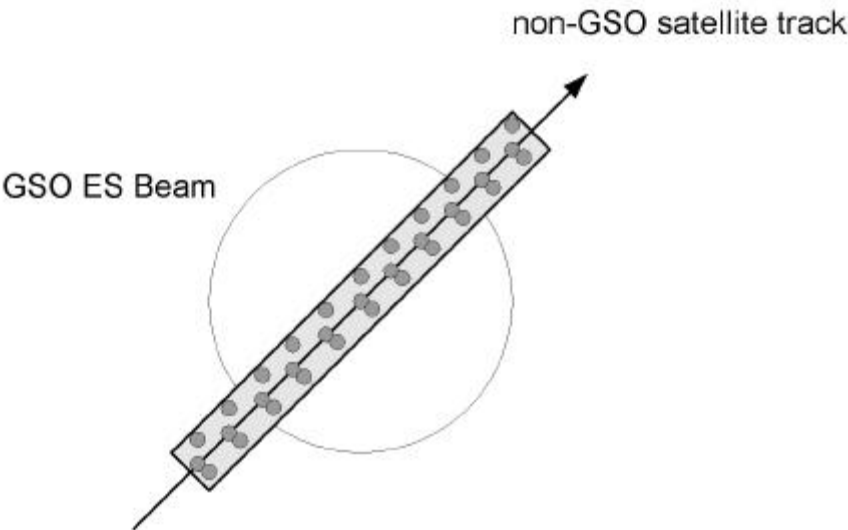
< 2.3> in-line event
 NGSO . ,
 가 (2.1)
 , GSO NGSO



< 2.3>

3.

EPFD /
time step
< 2.4>
Station keeping 가 Repeating Ground
Track , < 2.11>
.



< 2.4> Repeating Ground Tracks

< 2.11> Repeating Ground Track

Constellation	yes or no
N_s	(=10)
P_{repeat}	Constellation [sec]
N_{track}	track (=5)

, 가 N_{\min} .

$$N_{\min} = \frac{100N_s}{(100 - (ITU \text{ S. 22 } 100\% \text{ } \%))} \quad (2.6)$$

가 T_{step}
 $N_{repsteps}$ (2.7) , $N_{repsteps}$ 가
 (2.8) 가 T_{step}'
 .

$$N_{repsteps} = \frac{P_{repeat}}{T_{step}} \quad (2.7)$$

$$T_{step}' = \frac{T_{step}(1 + N_{repsteps})}{N_{repsteps}} \quad (2.8)$$

$$T_{step} (T_{step}') \quad (2.9) \quad , \quad \text{constellation}$$

(2.10) .

$$T_{sig} = N_{min} \cdot T_{step} \quad (2.9)$$

$$N_{rep} = round\left(\frac{T_{sig}}{P_{repeat}}\right) \quad (2.10)$$

constellation (

2.11) (2.12) , time

step (2.13) .

$$N_{run} = \max(N_{rep}, N_{tracks}) \quad (2.11)$$

$$T_{run} = N_{run} \cdot P_{repeat} \quad (2.12)$$

$$N_{steps} = round\left(\frac{T_{run}}{T_{step}}\right) \quad (2.13)$$

3 PFD/EIRP mask

1 PFD mask

NGSO PFD
PFD

.

$$pfd = 10 \log \left(\sum_i^{N_{co}} 10^{pfd_{co_i}/10} + \sum_j^{N_{cross}} 10^{pfd_{cross_j}/10} \right) \quad (3.1)$$

,

$$pfd_{co_i} = P_i + G_i - 10 \log_{10}(4\pi d^2) \text{ [dBW/m}^2\text{]} \quad (3.2)$$

$$pfd_{cross_j} = P_j + G_{cross_j} - 10 \log_{10}(4\pi d^2) \text{ [dBW/m}^2\text{]} \quad (3.3)$$

p_i : i
[dBW/REFBW]

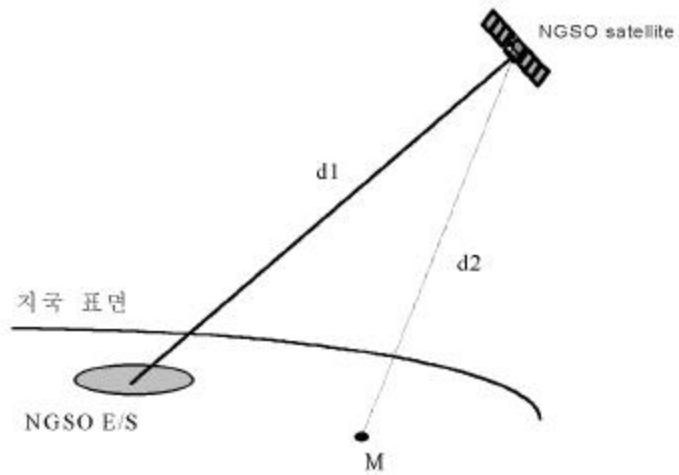
G_i : i

d : NGSO [m]

N_{co} :

N_{cross} :

< 3.1> NGSO NGSO
, NGSO 가
PFD .



< 3.1> NGSO 가

F-SAT MULTI-1B[2]

G_i u .

$$\frac{G(u)}{G_{\max}} = \left| \frac{2 \cdot J_1(u)}{u} \prod_{i=1}^3 \frac{1 - \frac{u^2}{\pi^2 * 1.1692^2 * [0.95277^2 + (i - 1/2)^2]}}{1 - [\frac{u}{\pi \mu_i}]} \right|^2 * \frac{4\pi d_1^2}{4\pi d_2^2} \quad (3.4)$$

,

μ_1, μ_2, μ_3 : Bessel

d_1 : NGSO GSO

d_2 : NGSO

$$u \qquad \qquad \qquad .$$

$$u = \frac{\pi}{\lambda} \sqrt{(L_r \sin \theta \cos \phi)^2 + (L_t \sin \theta \sin \phi)^2} \qquad (\quad 3.5)$$

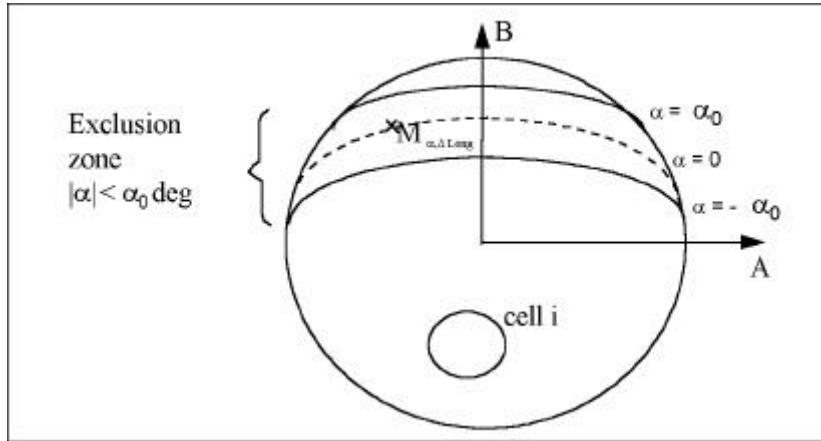
$$\begin{aligned} & , \\ (\theta, \phi) : \\ L_r, L_t \quad & : \\ & \qquad \qquad \qquad \text{(transverse)} \qquad \qquad \qquad \text{(effective radiating)} \\ & \qquad \qquad \qquad , \quad \theta \qquad \qquad \qquad . \end{aligned}$$

$$< \quad 3.1 > \qquad \qquad \qquad L_r, \quad L_t$$

θ	[0 ; 40)	[40;47)	[47;49)	[49;52.5)	[52.5;54)
$\frac{L_r}{\lambda}$	$\frac{0.74}{\sin a}$	$\frac{0.64}{\sin a}$	$\frac{0.51}{\sin a}$	$\frac{0.32}{\sin a}$	12.57
$\frac{L_t}{\lambda}$	$\frac{0.74}{\sin b}$	$\frac{0.64}{\sin b}$	$\frac{0.64}{\sin b}$	$\frac{0.65}{\sin B}$	4.84

$$\begin{aligned} \text{a} : & \qquad \qquad \qquad 1/2 \\ \text{b} : & \qquad \qquad \qquad 1/2 \end{aligned}$$

PFD mask



< 3.2> NGSO Exclusion Zone

cell N_{total}

< 3.3> < 3.4> iso-

iso- L

< 3.2> , L iso- n

$M_{\alpha, k} (k=1,2,...,n)$

PFD

$M_{\alpha, k} (k=1,2,...,n)$

PFD

Mitigation

L

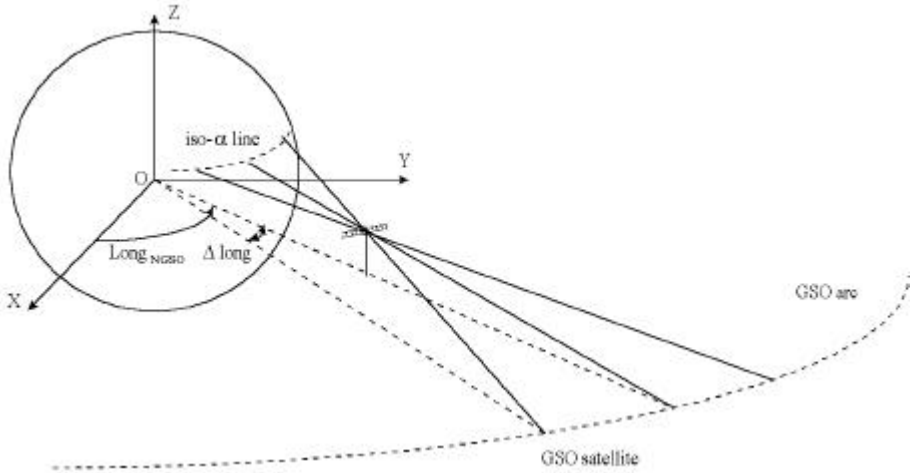
PFD

$$pfd\left(\alpha,\Delta L\right)=\max_{k=1,2,\dots,n}\left[pfd\left(M_{\alpha,k}\right)\right]\tag{3.6}$$

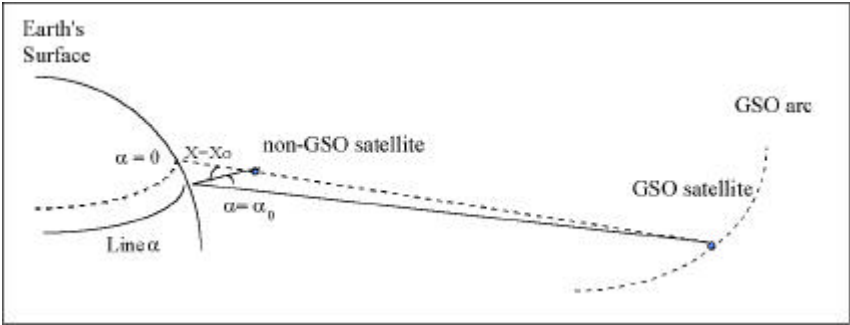
PFD sub-satellite point ()

PFD mask .

NGSO 1 PFD mask .



< 3.3> iso-



< 3.4> , X

2

EIRP mask

EIRP (3.7) off- axis
EIRP , NGSO
가 .

$$EIRP(\theta) = G(\theta) + P \text{ [dBW/RAFBW]} \quad (3.7)$$

,

θ : off- axis [degrees]

P :

[dBW/RAFBW]

$G(\theta)$: [dBi]

3

NGSO

< 3.5> NGSO exclusion zone
switch on switch off PFD

.

1) NGSO switch on

NGSO exclusion zone switch on

가 가 .

1 : NGSO GSO

In-line (=0 (X=0))

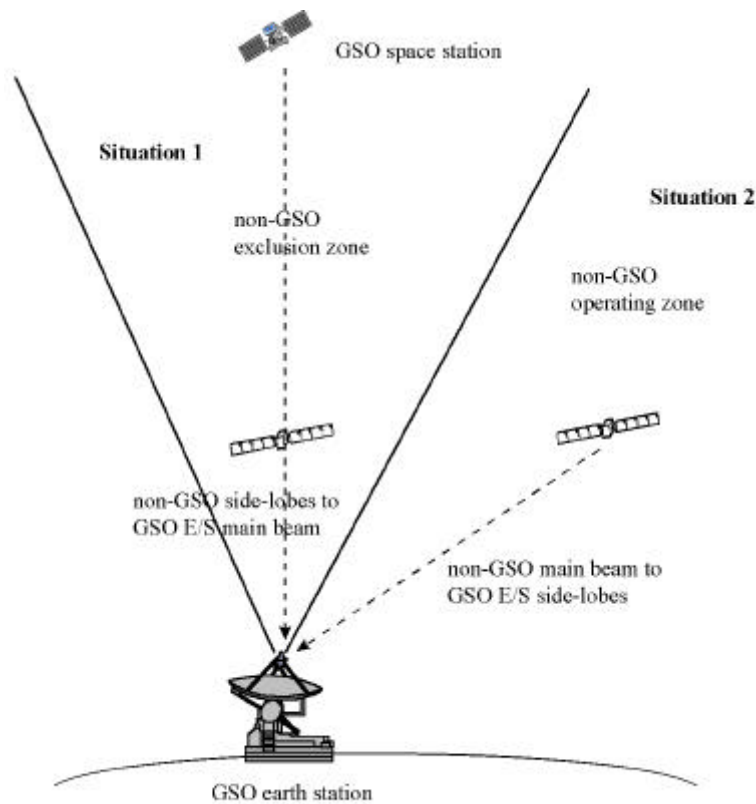
2 : NGSO GSO

(=± 0 (X=± X0))

2) NGSO switch off

NGSO exclusion zone 가

가 . (=± 0 (X=± X0))



< 3.5> NGSO

1.

NGSO exclusion zone switch off
switch on .

$PDF_{\Delta L}(\alpha = \alpha_0, \Delta L) \frac{G(\theta)}{G_{\max}}$ 가 NGSO

L .

NGSO (non- GSO lat) L

.

$\max_{\Delta L} PFD(\alpha = \alpha_0, \Delta L) \frac{G(\theta)}{G_{\max}} - PFD(\alpha = 0, \Delta L) > 0$
 $= 0$ 가 , =0
 가 .
 NGSO (non-GSO lat) L .
 non-GSO lat NGSO .
 NGSO .
 GSO .
 NGSO exclusion zone switch off
 0 가 NGSO
 GSO 0 GSO
 .
 NGSO exclusion zone =0
 가 =0 GSO
 .
 GSO .

4

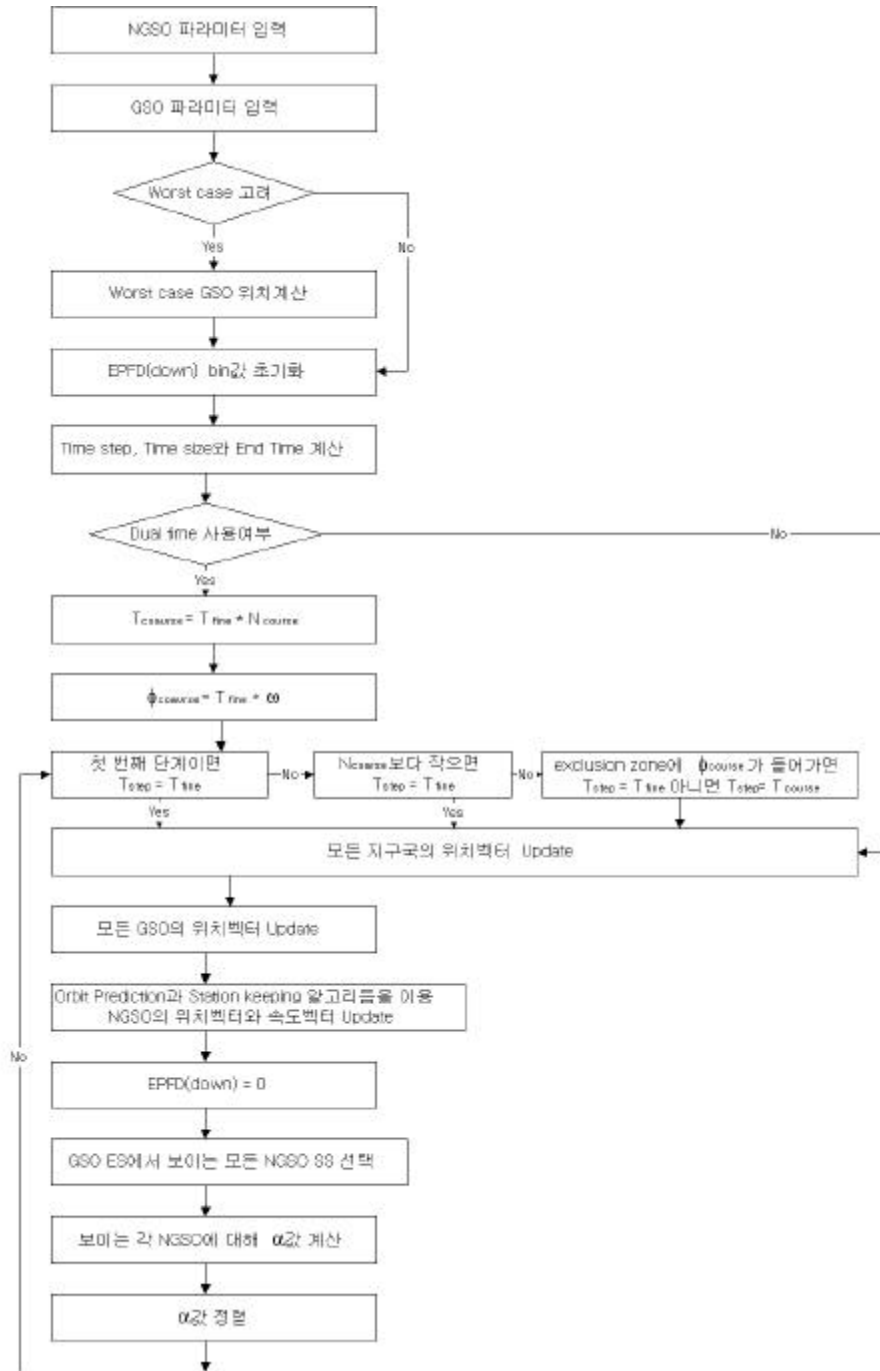
1

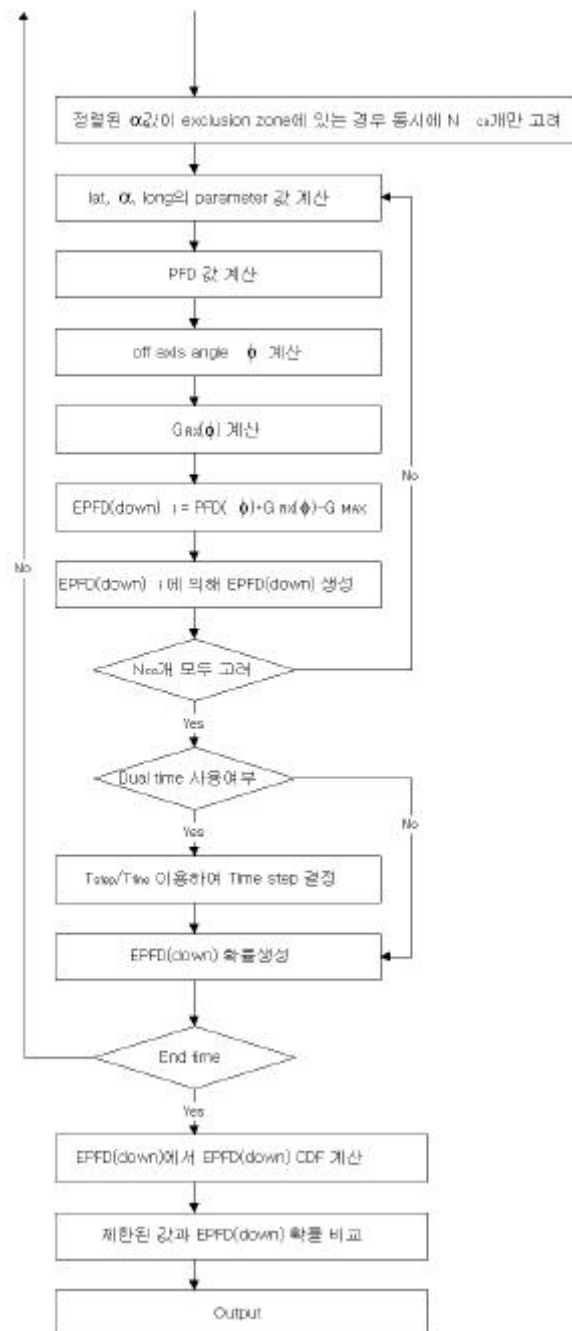
Flow chart

< 4.1>

flow chart

.





< 4.1> flow chart

2

.

<1> < 4.1> NGSO

< 4.1> NGSO

Nsat	NGSO
Nfreq	/
One of 1,2 or 3	
F_DOWNsat	[GHz]
" " "X"	Exclusion zone
MIN_EXCLUDE	Exclusion zone [degrees]
Nco[Latitude]	fsat
"Yes" or "No"	NGSO orbit station keeping
"Yes" or "No"	node precession rate
Wdelta	(station keeping) [degrees]
H_MIN	가 operating [Km]
PFD[N]	PFD Mask
A[N]	Semi- major axis [Km]
E[N]	
I[N]	[degrees]
O[N]	[degrees]
W[N]	[degrees]
V[N]	[degrees]

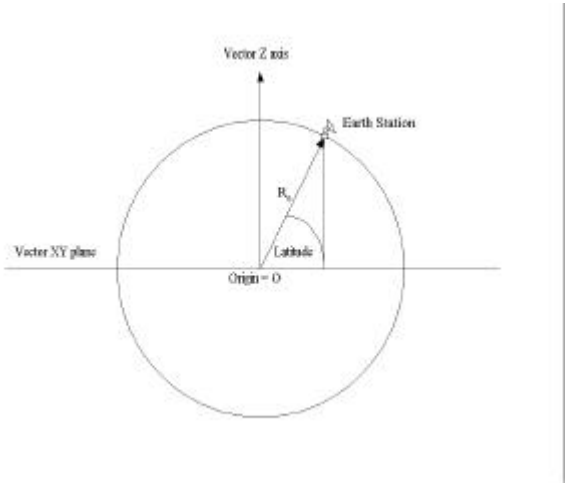
<2> < 4.2> GSO

.

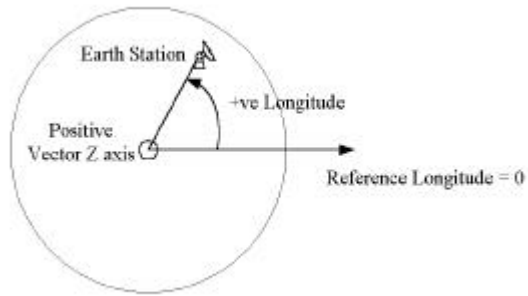
< 4.2> GSO

GSO_LONG	GSO [degrees]
GSO_ES_LAT	GSO ES [degrees]
GSO_ES_LONG	GSO ES [degrees]
GSO_ES_PATTERN	ES
GSO_ES_D_ANT	ES [meters]

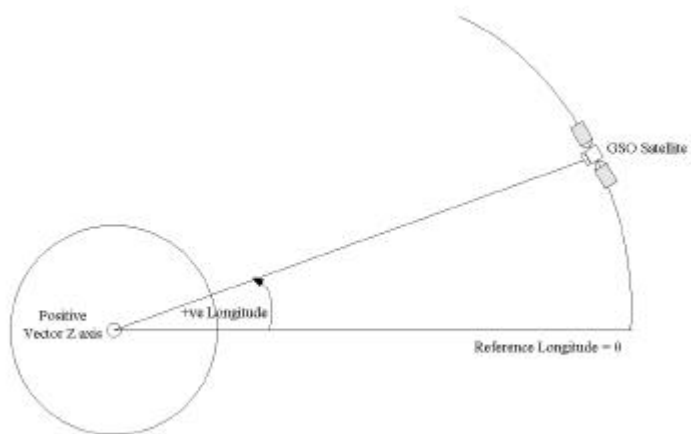
< 4.2> Latitude XY
, < 4.3> Longitude XY



< 4.2> GSO



< 4.3> GSO



< 4.4> GSO

<3> .(3 3)

<4> EPFD(down) bin .

<5> Time step, Time size End time .

(2 2)

<6> Dual time .

Dual time EPFD(down)

Time step Tfine .

ø coarse T coarse NGSO가 .

<7> update .

$$long = \arccos\left(\frac{x}{\sqrt{x^2 + y^2}}\right) \quad \text{if } x \geq 0$$

$$long = -\arccos\left(\frac{x}{\sqrt{x^2 + y^2}}\right) \quad \text{if } x < 0 \quad (4.1)$$

$$lat = \arctan\left(\frac{z}{\sqrt{x^2 + y^2}}\right) \quad (4.2)$$

$$x = R_e \cos(lat) \cos(long + \Omega_e t) \quad (4.3)$$

$$y = R_e \cos(lat) \sin(long + \Omega_e t) \quad (4.4)$$

$$z = R_e \sin(lat) \quad (4.5)$$

,

lat :

long :

t :

R_e :

Ω_e :

<8> GSO update .

$$long = \arccos\left(\frac{x}{\sqrt{x^2 + y^2}}\right) \quad \text{if } x \geq 0$$

$$long = -\arccos\left(\frac{x}{\sqrt{x^2 + y^2}}\right) \quad \text{if } x < 0 \quad (4.6)$$

$$lat = 0 \quad (4.7)$$

$$x = R_{gso} \cos(lat) \cos(long + \Omega_e t) \quad (4.8)$$

$$y = R_{gso} \cos(lat) \sin(long + \Omega_e t) \quad (4.9)$$

$$z = R_{gso} \sin(lat) \quad (4.10)$$

,

lat : GSO

long : GSO

t :

R_{gso} : GSO

Ω_e :

<9>

station keeping

NGSO

update

. GSO ES

,

NGSO

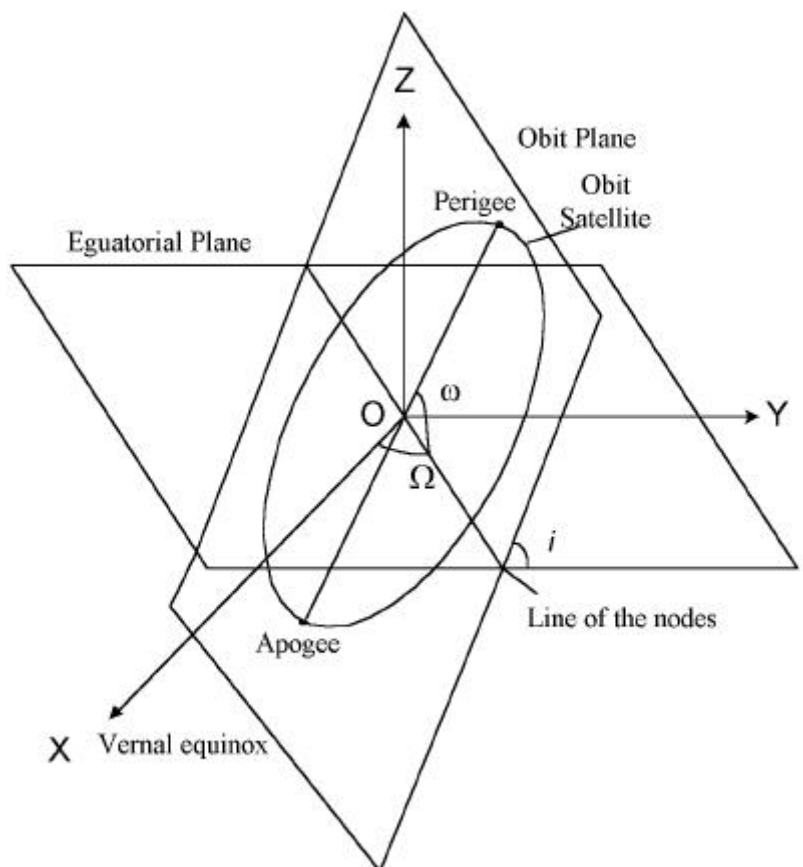
update

T_{step}

GSO, NGSO,

. NGSO

.



< 4.5> NGSO

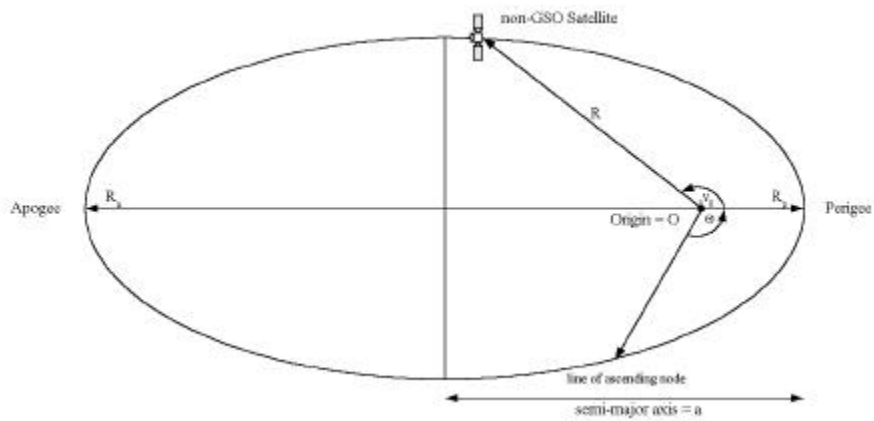
< 4.5> 2

Ω () :

i () :

non-GSO

< 4.6>



< 4.6> NGSO

$$a = (R_a + R_p)/2 \quad (4.11)$$

$$e = (R_a - R_p)/(R_a + R_p) \quad (4.12)$$

,

a :

e :

R_a :

R_p :

: , line

0 :

$$p = a (1 - e^2) \quad (4.13)$$

$$R = \frac{p}{1 + e \cos(v)} \quad (4.14)$$

$$T = 2\pi \sqrt{\frac{a^3}{\mu}} \quad (4.15)$$

$$M = E - e \sin E \quad (4.16)$$

$$\tan \frac{v}{2} = \sqrt{\frac{1+e}{1-e}} \tan \frac{E}{2} \quad (4.17)$$

,

p :

E : (Eccentric anomaly)

M : (Mean anomaly)

T : NGSO

R : NGSO

precession ;

$$\Omega_r = - \frac{J_\alpha \cos(i)}{p^2 \sqrt{a^3} \mu} \quad (4.18)$$

($i < 90^\circ$)

($i > 90^\circ$) 가 .

Precession ;

$$\omega_r = \frac{J_\alpha (5 \cos^2(i) - 1)}{2p^2 \sqrt{a^3} \mu} \quad (4.19)$$

$i=0$ $i=180$ Precession rate
가 . $i_1=63^{\circ} 26' 06$ $i_2=116^{\circ} 33' 54$
Precession rate 0 . $i < i_1$ $i > i_2$
precession $i_1 < i < i_2$
.

$$\omega = \omega_0 + \omega_r t \quad (4.20)$$

,
 ω_0 :
 ω_r :

$$\Omega = \Omega_0 + \Omega_r t \quad (4.21)$$

,
 Ω_0 :
 Ω_r :

$$x = R (\cos (v + \omega) \cos (\Omega) - \sin (v + \omega) \sin (\Omega) \cos (i)) \quad (4.22)$$

$$y = R (\cos (v + \omega) \sin (\Omega) + \sin (v + \omega) \cos (\Omega) \cos (i)) \quad (4.23)$$

$$z = R \sin (v + \omega) \sin (i) \quad (4.24)$$

$$\langle 10 \rangle \text{ EPFD(down) } = 0$$

- <11> GSO NGSO .
- <12> NGSO .
- <13>
- <14> exclusion zone operating GSO
ES NGSO Nco .
- <15> parameter(lat, , long) .

$$long = \arccos\left(\frac{x}{\sqrt{x^2 + y^2}}\right) \quad \text{if } x \geq 0$$

$$long = -\arccos\left(\frac{x}{\sqrt{x^2 + y^2}}\right) \quad \text{if } x < 0 \quad (4.25)$$

$$lat = \arctan\left(\frac{z}{\sqrt{x^2 + y^2}}\right) \quad (4.26)$$

- <16> PFD .(3)
- <17> offaxis angle \varnothing .
, \varnothing GSO ES GSO NGSO .
- <18> GRX(\varnothing) .

$$20 \leq \frac{D}{\lambda} \leq 100$$

$$G(\varphi) = G_{MAX} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda} \varphi\right)^2 \text{ dBi} \quad 0 < \varphi < m \quad (4.27)$$

$$G(\varphi) = G_1 \text{ dBi} \quad m \left(95 \frac{\lambda}{D}\right) \quad (4.28)$$

$$G(\varphi) = 29 - 25 \log \varphi \text{ dBi} \quad \left(95 \frac{\lambda}{D}\right) \leq \varphi < 10^{(38/25)} \text{ }^\circ \quad (4.29)$$

$$G(\varphi) = -9 \text{ dBi} \quad 10^{(38/25)} \text{。} < \varphi \leq 80 \text{。} \quad (4.30)$$

$$G(\varphi) = -4 \text{ dBi} \quad 80 \text{。} < \varphi \leq 120 \text{。} \quad (4.31)$$

$$G(\varphi) = -9 \text{ dBi} \quad 120 \text{。} < \varphi \leq 180 \text{。} \quad (4.32)$$

$$\begin{aligned} & , D = \\ & = \\ & = \text{offaxis} \quad (\text{degrees}) \end{aligned}$$

$$G_{MAX} = 20 \log \left(\frac{D}{\lambda} \right) + 7.7 \text{ dBi} \quad (4.33)$$

$$G_1 = 29 - 25 \log \left(95 \frac{D}{\lambda} \right) \text{ dBi} \quad (4.34)$$

$$\varphi_m = \frac{20\lambda}{D} \sqrt{G_{MAX} - G_1} \text{ (degrees)} \quad (4.35)$$

$$\frac{D}{\lambda} > 100$$

$$G(\varphi) = G_{MAX} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda} \varphi \right)^2 \text{ dBi} \quad 0 < \varphi < \varphi_m \quad (4.36)$$

$$G(\varphi) = G_1 \quad \varphi_m \leq \varphi \leq \varphi_r \quad (4.37)$$

$$G(\varphi) = 29 - 25 \log \varphi \text{ dBi} \quad \varphi_r \leq \varphi < 10 \text{。} \quad (4.38)$$

$$G(\varphi) = 34 - 30 \log \varphi \text{ dBi} \quad 10 \text{。} \leq \varphi < 10^{(46/30)} \text{。} \quad (4.39)$$

$$G(\varphi) = -12 \text{ dBi} \quad 10^{(46/30)} \text{。} \leq \varphi < 80 \text{。} \quad (4.40)$$

$$G(\varphi) = -7 \text{ dBi} \quad 80 \text{。} \leq \varphi < 120 \text{。} \quad (4.41)$$

$$G(\varphi) = -12 \text{ dBi} \quad 120 \text{。} \leq \varphi \leq 180 \text{。} \quad (4.42)$$

$$G_{MAX} = 20 \log \left(\frac{D}{\lambda} \right) + 8.4 \text{ dBi} \quad (4.43)$$

$$G_1 = -1 - 15 \log \left(\frac{D}{\lambda} \right) \text{ dBi} \quad (4.44)$$

$$\varphi_m = \frac{20\lambda}{D} \sqrt{G_{MAX} - G_1} \quad (\text{degrees}) \quad (4.45)$$

$$\varphi_r = 15.85 \left(\frac{D}{\lambda} \right)^{-0.6} \quad (\text{degrees}) \quad (4.46)$$

$$\langle 19 \rangle \text{ EPFD}(\text{down})_i = \text{PFD}(\varnothing) + \text{GRX}(\varnothing) - \text{GMAX} \quad (4.47)$$

$$i \quad \text{NGSO} \quad \text{EPFD}(\text{down})_i \quad .$$

$$, \text{GMAX} \quad \text{GSO ES} \quad .$$

$$\langle 20 \rangle \text{ EPFD}(\text{down})_i \quad \text{EPFD}(\text{down}) \quad .$$

$$\langle 21 \rangle N_{\infty} \quad .$$

$$N_{\infty} \quad \langle 15 \rangle \quad .$$

$$\langle 22 \rangle \text{ dual time} \quad T_{\text{step}}/T_{\text{fine}} \quad \text{Time step} \quad .$$

$$\langle 23 \rangle \quad \text{EPFD}(\text{down}) \quad .$$

$$\langle 24 \rangle \text{ End time} \quad .$$

- Dual time \quad End time \quad \langle 6 \rangle

- Dual time \quad End time \quad \langle 7 \rangle

$$\langle 25 \rangle \quad \text{EPFD}(\text{down}) \quad \text{EPFD}(\text{down}) \quad \text{CDF} \quad .$$

$$CDF_i = 100 \times \left(1 - \sum_{PDF_{min}}^{PDF_i} PDF \right) \quad (4.48)$$

PDF_x : PDF 1 X dB PDF
 71 PDF

<26> EPFD mask EPFD(down) .

i .

pdf (Ji Pi) .

CDF Ji Pt .

Pi < Pt Pass , Fail

<27> Output

- Test Pass/Fail
- CDF
- < 4.3> Summary

< 4.3> Summary Table

Specification Point			Simulation Point
pdf			
J1 dBW/(m2REFBW)	P1	Pass/Fail	Py
:	:	:	:
Ji dBW/(m2REFBW)	Pi	Pass/Fail	Py

5

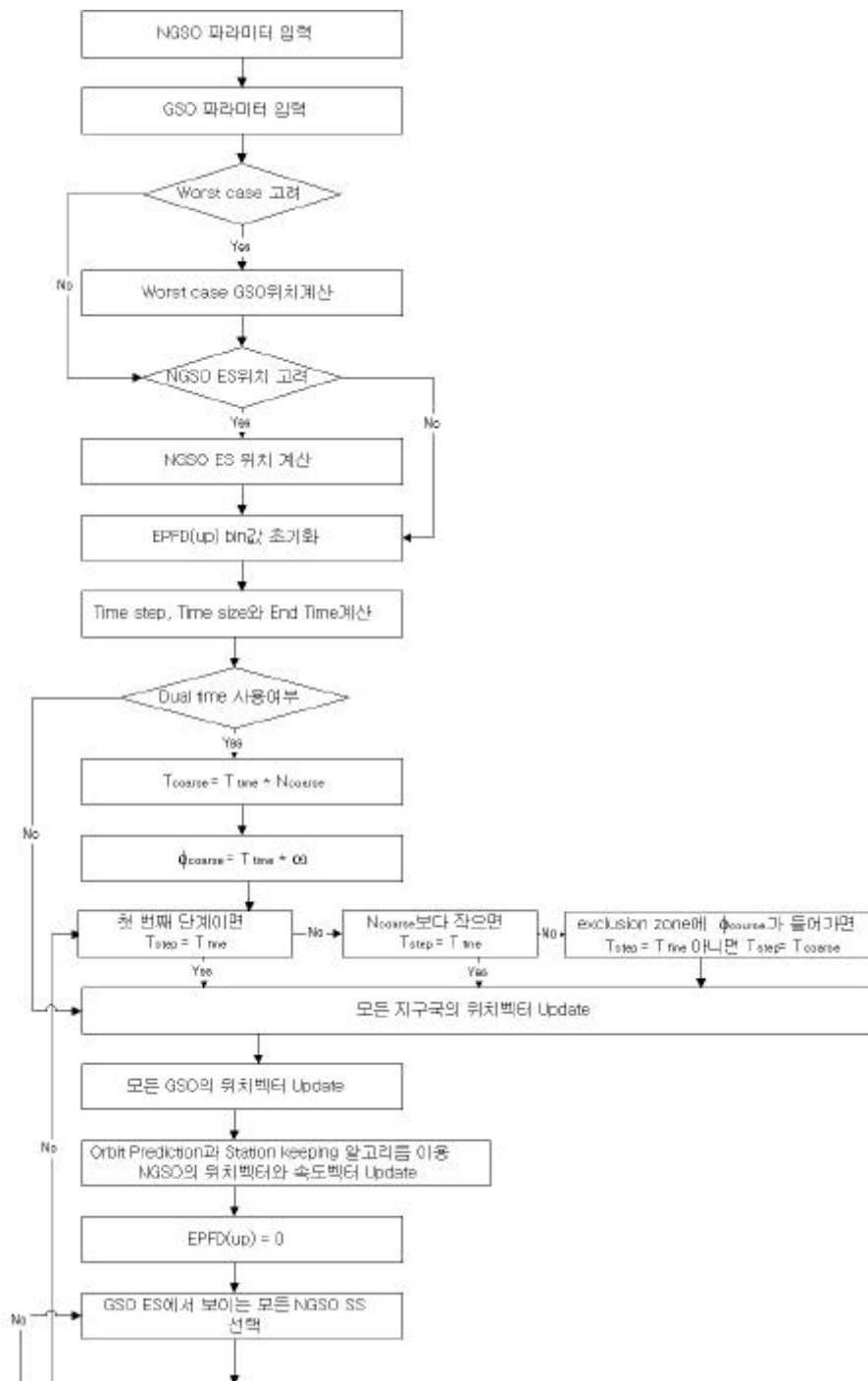
1

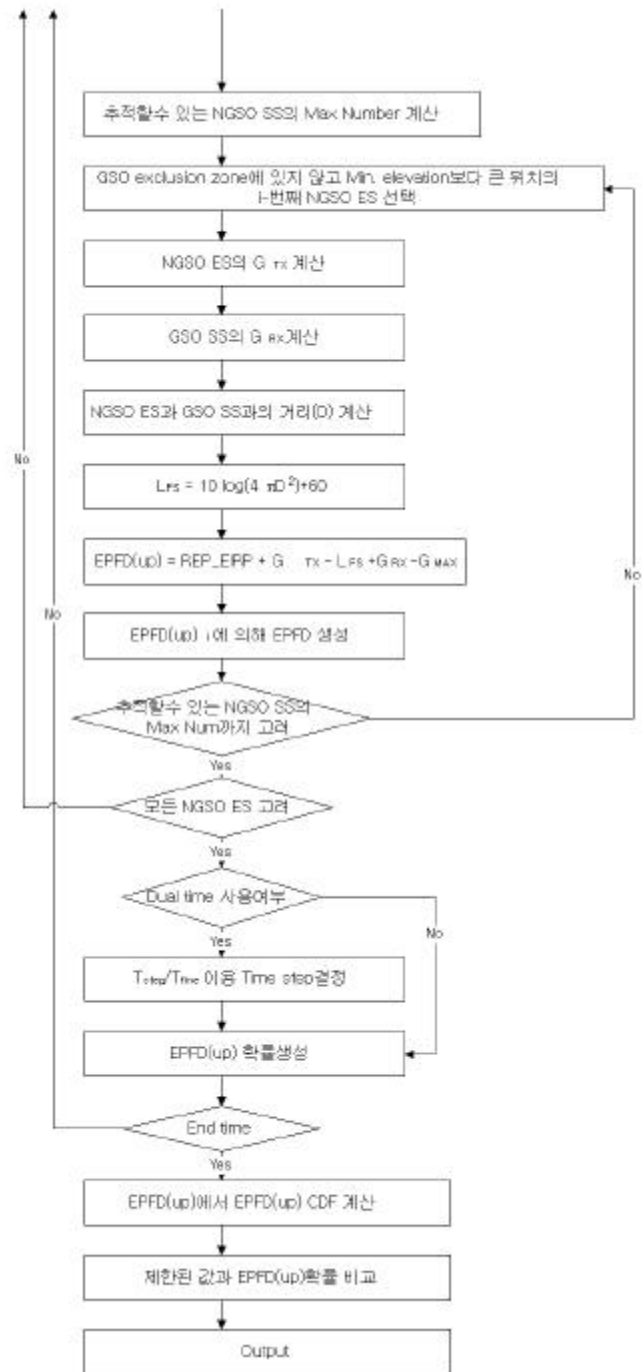
Flow chart

< 5.1>

flow chart

.





< 5.1> flow chart

2

<1> < 5.1> NGSO

< 5.1> NGSO

N_{sat}	NGSO
"Yes" or "No"	repeating ground track
"Yes" or "No"	node precession rate
W_{delta}	Station Keeping Range(ascending node) [degrees]
A[N]	- [km]
E[N]	
I[N]	[degrees]
O[N]	[degrees]
W[N]	[degrees]
V[N]	(anomaly) [degrees]

< 5.1> [N]
N- th N- th .

<2> < 5.2> GSO .

< 5.2> GSO

GSO_SAT_LONG	GSO [degrees]
BS_LAT	GSO Boresight [degrees]
BS_LONG	GSO Boresight [degrees]
GSO_SAT_PATTERN	

<3> . (3 3)

<4> NGSO ES .

NGSO ES .

$$\text{NUM_ES} = \text{ES_DISTANCE} \times \text{ES_DISTANCE} \times \text{ES_DENSITY} \tag{ 5.1}$$

non- GSO ES EIRP

$$\text{REP_EIRP} = \text{ES_EIRP} + 10\log(\text{NUM_ES}) \tag{ 5.2}$$

15dB GSO

,
ES_DISTANCE ES_DISTANCE
, REP_EIRP NGSO ES .
<5> EPFD(up) bin .
<6> Time step, Time size End time .
<7> time step <8> <24> .
Dual time , end time
<7> <22> .
<8> update .
<9> non- GSO update .
<10> GSO update .
<11> EPFD(up) = 0
<12> non- GSO ES <13> <23> .
<13> non- GSO ES GSO .
<14> <15> <23> .
<15> 가 non- GSO <16> <23>
.
<16> GSO exclusion zone elevation
i- .
<17> <18> <23> .
<18> GSO non- GSO ES G_{TX}
(dB) . (4)
<19> GSO G_{RX} (dB)[3]
.

$$G_{RX}(\phi) = G_m - 3(\phi/\phi_0)^2 \text{ dBi} \quad (\phi_0 \leq \phi \leq a\phi_0) \quad (5.3)$$

$$G_{RX}(\phi) = G_m + L_s \text{ dBi} \quad (a\phi_0 < \phi \leq b\phi_0) \quad (5.4)$$

$$G_{RX}(\phi) = G_m + L_s + 20 - 25 \log(\phi/\phi_0) \text{ dBi} \\ (bi_0 < \phi \leq \phi_1) \quad (5.5)$$

$$G_{RX}(\phi) = 0 \text{ dBi} \quad (\phi_1 < \phi) \quad (5.6)$$

,

$G_{RX}(\phi)$:

G_m :

ϕ :

ϕ_0 : 3dB

ϕ_1 : (5.1) 0dB가 ϕ

L_s : near-in-side-lobe level (dB)

a, b L_s < 5.3> .

< 5.3> L_s a, b

Ls(dB)	a	b
- 20	2.58	6.32
- 25	2.88	6.32
- 30	3.16	6.32

<20> NGSO ES GSO (km) .

<21> NGSO EPFD(up) .

$$\text{EPFD}(\text{up})_i = \text{REP_EIRP} + G_{TX} - L_{FS} + G_{RX} - G_{\max} \quad (5.7)$$

,

$$L_{FS} = 10\log(4\pi D^2) + 60 \quad (5.8)$$

<22> EPFD(up)_i EPFD(up) .

dual time step

. T_{step}/T_{fine} EPFD(up) .

<23> EPFD(up) .

<24> EPFD(up) EPFD(up) CDF

.

<25> EPFD mask EPFD(up) .

<26> Output

• 가 Test

Pass/Fail

6 EPFD

GSO ,

NGSO

EPFD GSO 가

1. [4]

Ku EPFD
EPFD .

$$EPFD = 64.23(2.19^{-\log D} - 4.12) + 7.747(3.37^{-\log D} - 1.78) \log\left(\frac{p}{100}\right) \quad (6.1)$$

, D GSO , p EPFD

2. [5]

, EPFD

$$EPFD = 4\pi \frac{I_0}{N_0} kT_{sys} \frac{BW_{ref}}{5.89D^2} \quad (D/\lambda < 100) \quad (6.2)$$

$$EPFD = 4\pi \frac{I_0}{N_0} kT_{sys} \frac{BW_{ref}}{6.92D^2} \quad (D/\lambda > 100) \quad (6.3)$$

,

k :

T_{sys} :

I_0 :

N_0 :

D :

BW_{ref} :

7

1

1.

GSO 1
(KOREASAT - 1) NGSO F- SAT
MULTI 1B[2] .

< 7.1> NGSO orbit parameter

	80	
	20	
	4	
	53	degrees
	115	min
	1469.3	km
	1469.3	km
argument of perigee	90	degree
	0	
	90	degree
	67.5	degree
	18	degree

< 7.2> NGSO

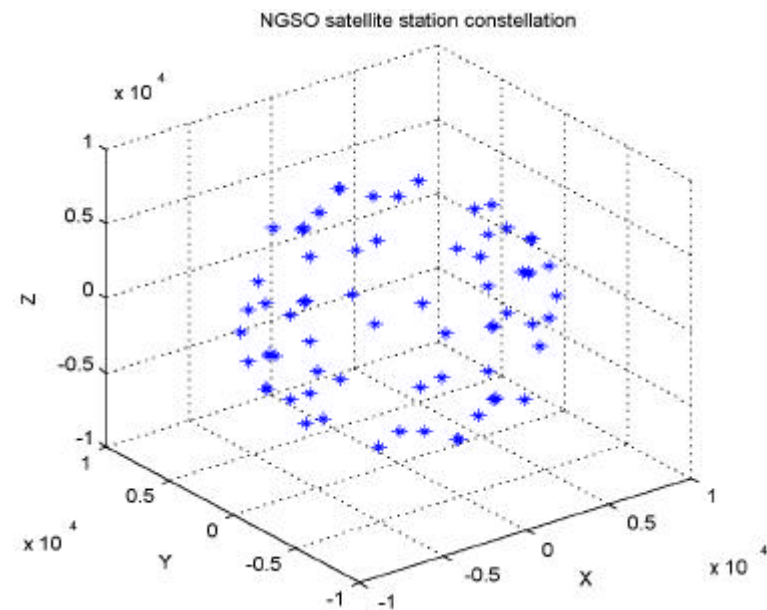
	250	MHz
EIRP	27.5	dBW
	12	
	12	
	20	dB

< 7.3> GSO

	TVRO	CATV	
	45	51.8	dB _i
	1.8	3.7	m
isolation	27	27	dB
	127	127	degree
	37.5	37.6	degree

2. NGSO

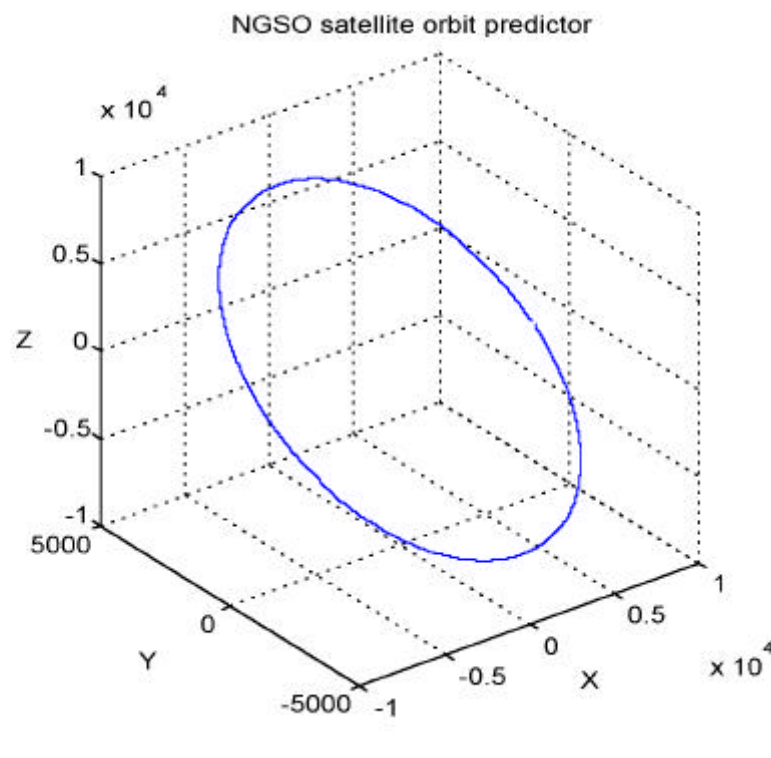
< 7.1> NGSO orbit parameter constellation MATLAB



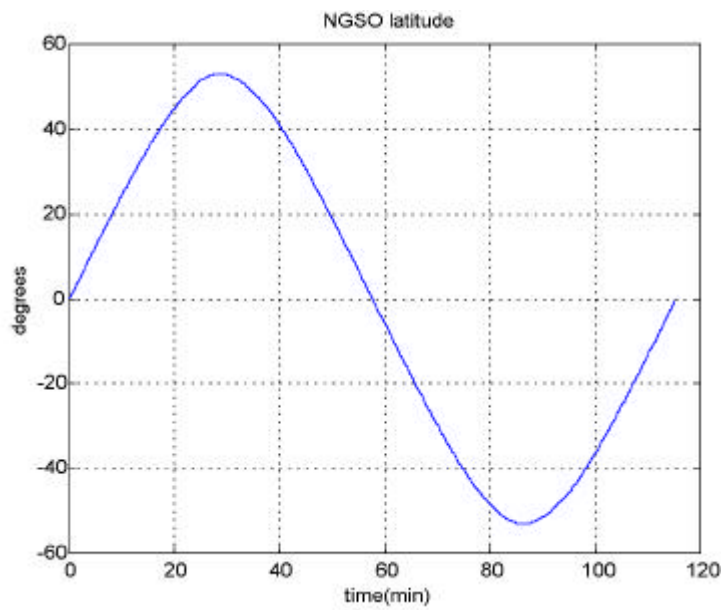
< 7.1> NGSO constellation

< 7.2> i()가 53. Ra() 7847.4km Rb() 7847.4km orbit predictor

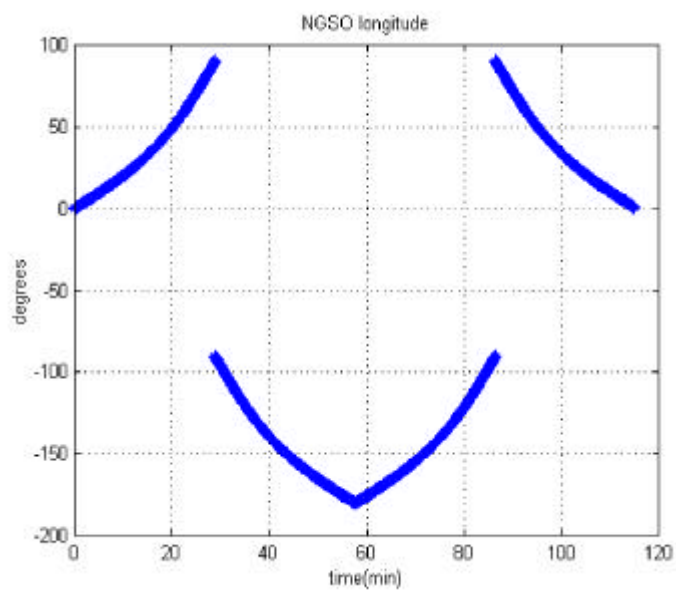
< 7.3> < 7.4>



< 7.2> NGSO



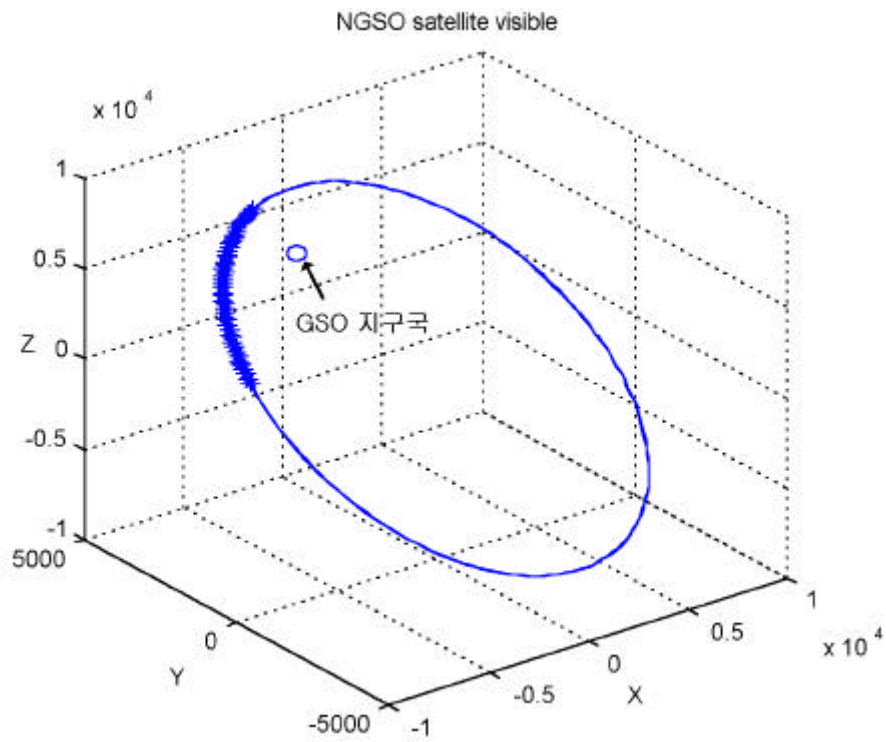
< 7.3> 53。 NGSO



< 7.4> 53。 NGSO

3. NGSO 가

()

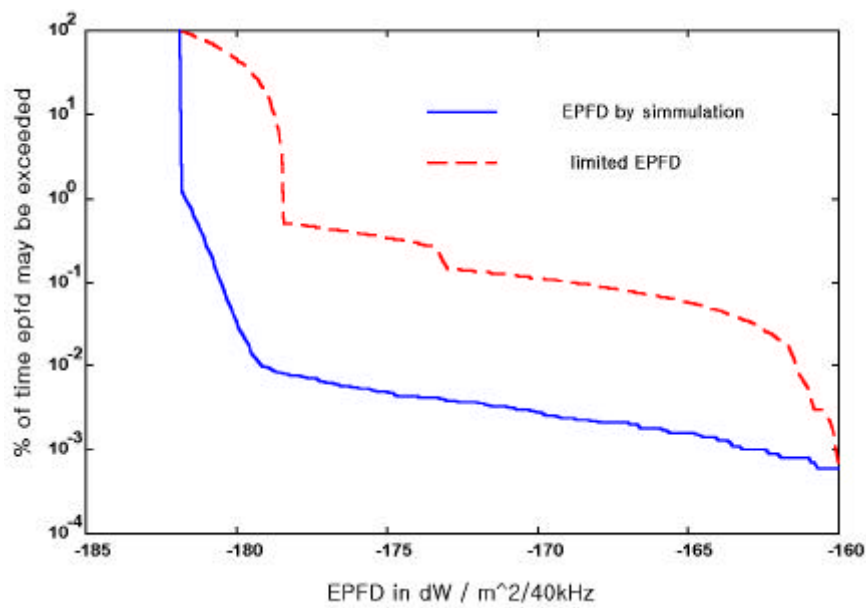


< 7.5> GSO NGSO

< 7.5> 37.5. 127. GSO
NGSO .

4. EPFD

Ku carrier TVRO
 (1.8m), CATV(3.7m)
 F-SAT MULTI 1B
 40kHz EPFD

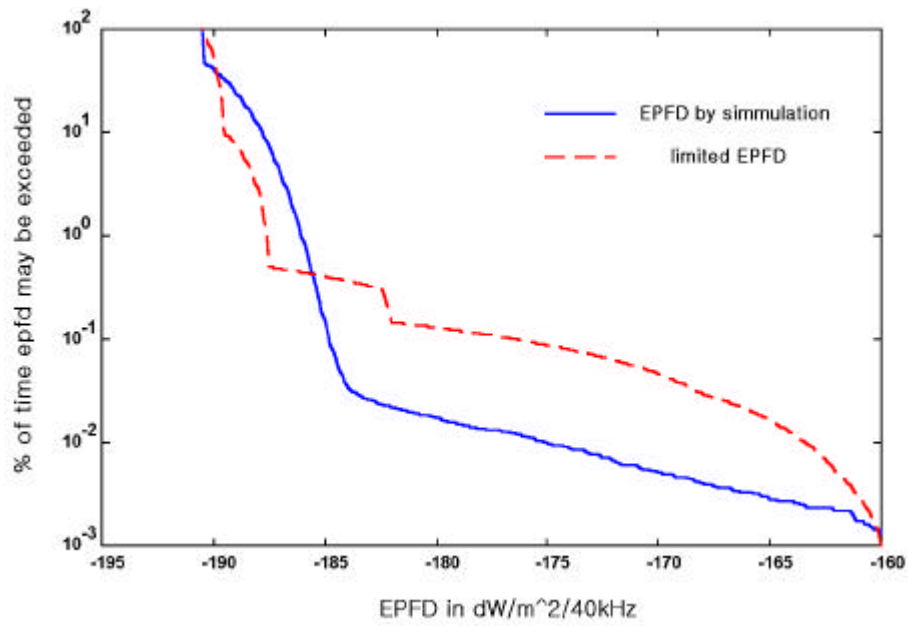


< 7.6> (TVRO, 1.8m) EPFD

< 7.6> F-SAT MULTI 1B TVRO
 (TVRO)

F-SAT MULTI 1B EPFD

,
 EPFD 3m , S22
 가 1.2m
 [6] TVRO
 , F-SAT MULTI 1B
 TVRO



< 7.7> (CATV, 3.7m) EPFD

< 7.7> F-SAT MULTI 1B CATV
 . 3.7m 가 , S22
 가 3m
 [6] . EPFD가 ,
 가 TVRO F-SAT
 MULTI 1B CATV

·
 , TVRO
 , CATV
 EPFD 가

2

1.

< 7.4>

	53.1	dBi
	0.36	degree
	29- 25log(θ)	dBi
EIRP/carrier	59.3	dBW
/carrier	22.6	MHz

< 7.5>

	45.6	dBi
	14.25	GHz

2. EPFD

F- SAT MULTI

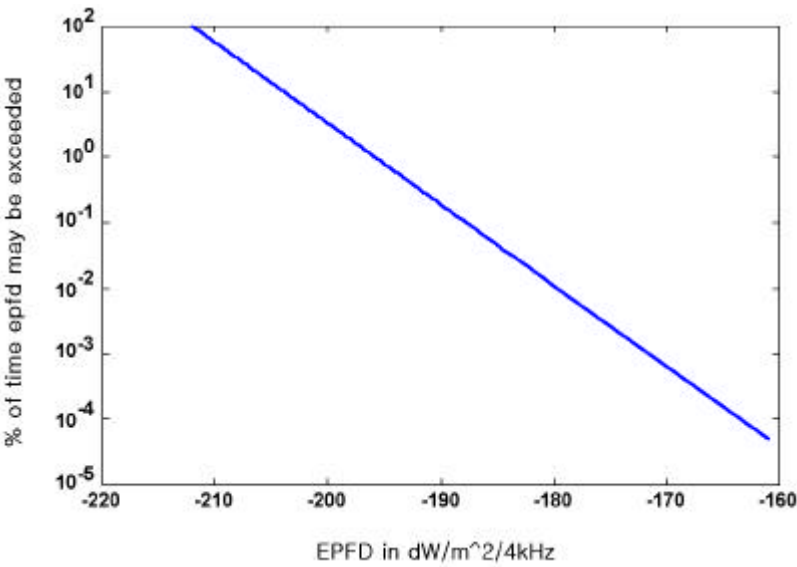
1B

EPFD - 160dB
1.1669% 가 0%

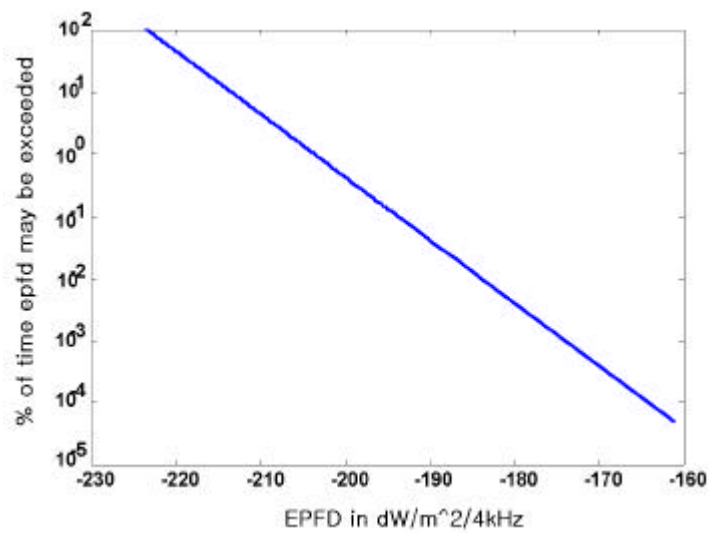
3 EPFD

EPFD
(KOREASAT - 1)

.
< 7.8> < 7.9> EPFD
1.8m(TVRO) 3.7m(CATV)
.

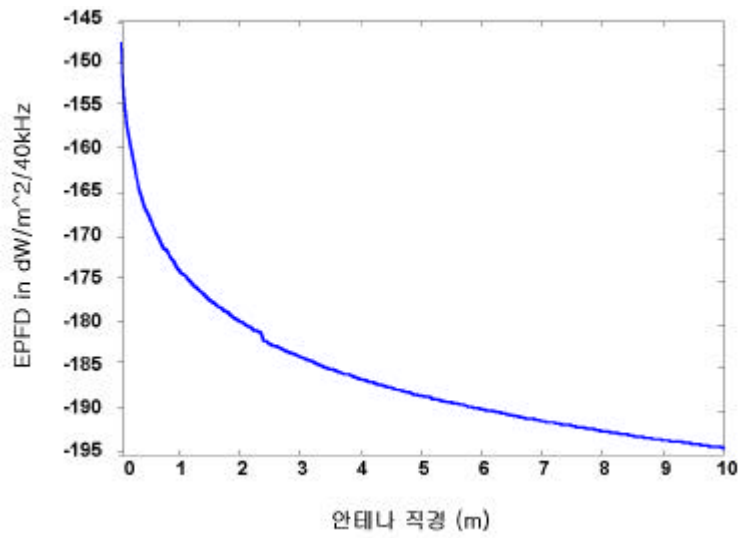


< 7.8> EPFD (1.8m)



< 7.9> EPFD (3.7m)

< 7.10> EPFD
40kHz, $I_0/N_0=0.02$.



< 7.10> EPFD ($I_0/N_0=0.02$)

NGSO 가 , GSO GSO EPFD 가 .

8

NGSO/FSS GSO/FSS
ITU-R ,
F-SAT MULTI 1B
.
가
가 .

2000

WRC- 2000

,

가

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- [1] Contribution ITU-R JTG 4-9-11, Functional description of software for use by BR/ITU in checking compliance of non-GSO FSS systems with EPFD limits
- [2] Contribution ITU-R JTG 4-9-11/260-E, DETAILED CHARACTERISTICS OF F-SAT MULTI 1B
- [3] RECOMMENDATION ITU-R S.672-4, SATELLITE ANTENNA RADIATION PATTERN FOR USE AS A DESIGN OBJECTIVE IN THE FIXED-SATELLITE SERVICE EMPLOYING GEOSTATIONARY SATELLITES
- [4] Contribution ITU-R JTG 4-9-11/313-E, United Kingdom, CONTINUOUS CURVES FOR S.22 EPFD LIMITS
- [5] Contribution ITU-R WP 4A/254-E, United States of America, METHODOLOGY TO DESCRIBE CONTINUOUS CURVES OF LONG-TERM EPFD LIMITS AS A FUNCTION OF ANTENNA SIZE
- [6] Contribution ITU-R JTG 4-9-11/408-E, Proposed text for Chapter 3 of the CPM-2000 Report (Coexistence of NGSO FSS, GSO FSS, Radiolocation , Radionavigation and Space Research)