The ITU Radiocommunication Assembly,

considering

a) that the World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (Malaga-Torremolinos, 1992) (WARC-92) has allocated to a number of satellite services, operating in the geostationary orbit, spectrum that is also allocated to the fixed service (FS);

b) that emissions from space stations operating in the geostationary orbit and sharing the same spectrum may produce interference in receiving stations of the FS;

c) that it may be impractical to coordinate between the many terrestrial stations and the many space stations, and that, therefore, sharing criteria should be established to preclude the need for detailed coordination;

d) that in devising such sharing criteria, account needs to be taken of the operational and technical requirements of networks in the satellite service as well as of the requirements of the FS and measures available to them;

e) that it has been determined that a probabilistic basis for developing sharing criteria results in a more efficient use of the spectrum than from criteria developed using worst case analysis;

f) that it is difficult and burdensome to assemble sufficient statistically accurate information about real existing and planned terrestrial and satellite system stations;

g) that computer simulations of FS and satellite services operating in the geostationary orbit can generate statistically accurate information suitable for determining sharing criteria for a wide variety of sharing scenarios,

recommends

1. that information derived from computer simulations of FS and satellite services operating from the geostationary orbit and using the same spectrum may be acceptable for developing sharing criteria;

2. that when deriving information for developing sharing criteria the material in Annex 1 should be taken into account.

ANNEX 1

Method of developing criteria for protecting the fixed service from emissions of space stations operating in the geostationary orbit

1. Introduction

WARC-92 allocated to the broadcasting-satellite service (TV and sound), the mobile-satellite service and the space science services spectrum which is also shared by the FS. WARC-92 also approved several Resolutions and Recommendations that requested the ITU-R resolve the sharing issues resulting from the various allocations. This Annex describes a methodology that will aid in the development of sharing criteria between the FS and those satellite services provided from the geostationary orbit.

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 4 (WP 4-9S), 7, 8 (WP 8D), 10 and 11 (WP 10-11S) and 2 (TG 2/2).
Recommendation ITU-R SF.358 proposes power flux-density (pfd) protective levels for the FS for some portions of the spectrum. Similarly Nos. 2561 to 2580.1 of Article 28 of the Radio Regulations provide definitive pfd limits for similar bands. Neither reference, however, addresses all the bands indicated by WARC-92 nor do they provide sufficient information on how to extend the criteria, other than by extrapolation, to different fixed and satellite service sharing scenarios.

Appendix 1 to Annex 1 of Recommendation ITU-R SF.358 does indicate that statistical simulation methods for determining pfd levels to protect the FS from satellites operating in the geostationary orbit are acceptable but it does not provide a detailed methodology for developing the data. This Annex describes the geometric considerations needed to calculate the data. It also provides a description and the basic language source code for a program that can generate data representative of many of the sharing scenarios that currently exist or will result from the WARC-92 allocations. The resulting program data can be analysed to determine the effects of satellite pfd levels on the FS for a variety of scenarios. Scenario differences can be determined by user input parameters to the program. Some examples are provided in Appendix 1 to this Annex of how the data from the simulation program can be utilized to help resolve WARC-92 or similar issues.

2. Geometric considerations

In order to calculate the interference into a radio-relay network from satellites in the geostationary orbit, it is necessary to identify all satellites visible to each radio-relay station. This may be accomplished by determining the limits of the visible geostationary orbit for each station and accordingly all satellites between those limits would be visible.

Figure 1 provides a representation of the geometry of the geostationary orbit and a radio-relay station. Some of the important parameters needed to calculate interference into the radio-relay station are:

\[ \theta \]: elevation angle of the satellite above the horizon
\[ \beta \]: spherical arc subtended by the sub-satellite point, S', and the radio-relay station, P
\[ \Omega \]: angle subtended by \( \beta \) as viewed from the satellite, S.

If the radio-relay antenna has 0° elevation and diffraction is ignored then the azimuth displacement, \( A \), measured from South, to the intersection of the horizon with the geostationary orbit can be calculated as:

\[
|A| = \cos^{-1} \left( \tan \frac{\theta}{(K^2 - 1)^{1/2}} \right)
\]  

where:

\[ K = \frac{R}{a} \]

\[ a \]: radius of the Earth
\[ R \]: radius of the geostationary orbit
\[ \varphi \]: latitude of the radio-relay station.

The relative longitudinal separation between the radio-relay station and the horizontal plane/geostationary orbit intercept can be expressed as:

\[
\lambda = \sin^{-1} \left( \sin \frac{\theta}{(1 - K^{-2})^{1/2}} \right)
\]  

Since the visible stationary orbit is symmetrical around the 0° azimuth line the total number of satellites visible to the station will appear in the longitudinal span of the orbit equal to \( 2\lambda \).

The azimuth \( A_z \) to each visible satellite is:

\[
A_z = \tan^{-1} \left( \tan \frac{\lambda_r}{\sin \varphi} \right)
\]

where \( \lambda_r \) is the difference between the longitude of the satellite and the radio-relay station, i.e. the relative longitude.
FIGURE 1
Geometry of the geostationary-satellite orbit and a radio-relay station
The ITU-R customarily limits or defines pfd levels from a satellite as a function of the elevation angle, $\theta$. The angle can be determined as follows:

$$\theta = \left(\frac{\pi}{2}\right) - (\beta + \Omega)$$  

(4)

where:

$$\beta = \cos^{-1} (\cos \varphi \cos \lambda_r)$$  

(5)

$$\Omega = \tan^{-1} \left( \frac{\sin \beta}{K - \cos \beta} \right)$$  

(6)

Generally pfd is defined in the form:

$$pfd_{low}$$: allowable level for low angles of arrival, usually expressed in dB(W/m²) in a 4 kHz band

$$pfd_{hi}$$: allowable level for high angles of arrival also expressed in dB(W/m²) in a 4 kHz band.

Finally the angle $\Delta$ between the incidence of the interfering satellite pfd level and the pointing direction of the radio-relay station receiver (Fig. 2) can be determined by:

$$\Delta = \cos^{-1} \left( \cos \theta \cos (A_z - \delta) \right)$$  

(8)

where $\delta$ is the pointing direction of the radio-relay station receiver relative to South.
If the radio-relay receive antenna gain is assumed to be equal in all planes (horizontal to vertical) then the gain in the direction of the interfering satellite, $G(\Delta)$, may be determined from the antenna gain pattern equations in Recommendation ITU-R F.699.

3. **Interference calculations**

The total interference power received at the radio-relay receiver can be determined by summing the contributions from each visible satellite. Each contribution can be determined as follows:

$$I_B = f(\theta) \times g(\Delta) \times \frac{\lambda^2}{4\pi h}$$  

(9)

where:

$$f(\theta) = 10^{F(\theta)/10}$$ (10)

$$g(\Delta) = 10^{G(\Delta)/10}$$ (11)

$\lambda$: wavelength of the carrier

$h$: feeder loss

Equation (9) contains the factor $\lambda / 4\pi h$ because $f(\theta)$ is in units of W/m² per 4 kHz.

4. **Network simulation for interference determination**

The selection of a methodology to select pfd values for protecting the FS is limited by very practical considerations. For example, it is theoretically possible to determine the interference effects of a satellite service on the FS by performing an exact calculation involving the convolution of all existing and planned transmissions of the satellite service against all existing and planned receptors of the FS while taking into account temporal, spatial and spectral factors. The practical considerations, however, in accumulating the requisite data for such a calculation, for even one type of sharing scenario, generally preclude this possibility.

Other methods of calculating protective criteria such as using “worst case” analysis may in certain cases be conservative for determining the use of a valuable and limited resource. Additionally, laboratory experiments do not lend themselves to convenient solutions for spatial and quantitative reasons. Finally, because of the uncertainty of being able to anticipate all of the situations which may develop, concerning new services or where continual evolution of existing services takes place, the results of any of the above techniques are subject to continual re-evaluation.

For these reasons, an analytic computer simulation of the problem is the most expedient method of getting useful results. Computer simulations using Monte Carlo methods for generating representative service implementations can create simulated data which can be used in place of actual or measured databases.

Appendix 1 provides a listing and description of a Monte Carlo implemented computer simulation that allows a variety of FS/satellite scenarios to be examined. The program can be used to test specific FS systems performance with specific satellite configurations emitting specific pfd levels. Iterative runs of the program can be used to determine the trade-offs of system parameters that would allow sharing.

Figures 3-7 provide results of appropriate example FS/satellite service sharing scenarios.
APPENDIX 1

Description of an example computer simulation program

1. Network assumptions

The satellite and radio-relay models implemented in the program assume that:

– the orbit is completely filled with uniformly spaced platforms, operating with the same level of effective radiated power and producing the same pfd on the earth surface; and

– the radio-relay network is composed of 50 hop routes randomly distributed over an approximately 65° by 22.5° longitude by latitude surface. All receivers have the same noise temperature, antenna characteristic (Recommendation ITU-R F.699), and spacing (50 km);

– free-space calculations are used. Atmospheric and polarity advantages are not considered.

2. Input/output

The simulation program allows operator selection and control of the following input parameters:

– latitude of the centre of the routes (trendline),
– receiver noise temperature,
– maximum receive antenna gain,
– number of radio-relay routes to be analysed,
– satellite spacing,
– orbit avoidance,
– low angle pfd,
– high angle pfd.

The program produces two output files containing databases that the user can analyse.

The first database (RAD.RTS.DAT) would appropriately be used to analyse the interference effects of analogue radio-relay networks for various satellite network configurations. The file is a series of records where each record gives the total baseband interference (pW) in a 4 kHz bandwidth for a 50 hop radio-relay route. The data could most typically be used to provide cumulative distribution graphs showing the amount of interference impairment that percentages of the analogue networks would experience as a function of the interference levels. The size of the file is twice the number of radio-relay routes analysed, since there are two directions for each route. The maximum size file will be 600 records and is a function of the maximum number of routes that can be handled by the program which is 300.

The second database file (RAD.STE.DAT) can similarly be used to analyse the effects of satellite interference on digital FS networks. Each record in the file is the interference (I) (W) input into a radio-relay site receiver. The records are arranged in groups of 50, so that analysis for each complete 50 hop route, in both directions, can be performed. Each route will produce 100 records (50 × 2). The maximum size file will contain 30 000 records (50 × 2 × 300).

In the event that the maximum size files from one computer run is not a sufficiently large enough sample of data, the program can be re-run and the subsequent data will be automatically appended.

3. Program operation

The program begins by selecting the user-specified latitude for the centre of the radio-relay route and then proceeds to calculate the longitude as a random variable (bounded by the 65° surface limits) of the centre of the route. The azimuth (relative to South) of the route direction or trendline, is calculated as a random variable with a uniform
distribution between 0 and $2\pi$. The location of the first radio-relay site is determined from the latitude, longitude and trendline angle. The sum of the interference into the site receiver from all visible satellites is then calculated and stored for further use.

The location of the next site on the route is determined by assuming that its direction is a uniformly distributed random variable within $\pm 25^\circ$ of the route trendline and that the route length is 50 km. Interference into the new site receiver from all visible satellites is again calculated as described above.

Next site selection and interference calculations are repeated for all 50 hops in the route wherein a new route is randomly selected and the interference calculation process is repeated for up to 300 times. In the event that orbit avoidance is to be considered (user option), the program tests each site to determine if the site direction falls within the range to be avoided. If it does, the site location is discarded and a new direction and site is chosen.

The stored interference information is used to create the output files (RAD_RTS.DAT, RAD_STE.DAT).

In the case of analogue networks the baseband interference is the desired information. The program derives this information by assuming that there is a linear relationship between the receiver input interference-to-noise ratio and the baseband interference-to-noise ratio as follows:

\[ \frac{i_c}{n_c} = \frac{i_b}{n_b} \]  \hspace{1cm} (12)

or:

\[ i_b = \left( \frac{i_c}{n_c} \right) n_b \]  \hspace{1cm} (13)

The receiver input interference is determined by the network characteristics as explained above is in main § 3 of Annex 1. Therefore:

\[ i_c = I_s \]  \hspace{1cm} (see equation (9))

The receiver thermal input noise is a function of the radio-relay system noise temperature

\[ n_c = k T_s b \]

where:

- $k$: Boltzmann’s constant
- $T_s$: system noise temperature
- $b$: voice channel bandwidth (4 kHz).

Recommendation ITU-R SF.358 indicates that for an appropriate radio-relay model the channel thermal noise power is:

\[ n_b = 25 \text{ pW0p} \]

The program uses this value to determine the baseband interference for each site receiver per equation (13) and sums all 50 site interferences for each route to determine the total interference per route.

The second file (RAD_STE.DAT) created by the program is a compilation of the $I_s$ values calculated.

Calculations made by the program are constrained by the following factors:

- The centre point of a route must lie between $15^\circ$ and $70^\circ$ latitude.
- The program assumes satellites are in exact equatorial planes, and does not allow for inclined orbits.
4. Sample scenario results

Figure 3 gives the results of an analysis of the RAD_RTS.DAT data for three 2 GHz sharing scenarios. All fixed systems were assumed to be 50 hop FDM routes implemented with 33 dB gain receive antennas and receivers with noise temperature of 1 750 K. These FS parameters are representative of those described in Recommendation ITU-R F.758. The three satellite network models considered limit pfd levels to –154 to –144 dB(W/m²) in 4 kHz and differ only in maximum orbit occupancy (9°, 12° and 24° spacing).

The results indicate that, for satellite spacings of 6° or more, the FDM FS systems would experience interference less than 1 000 pW in about 95% of the routes, assuming a uniform distribution of route directions. It also suggests that the FS might accept higher pfd levels from satellites with reduced orbit occupancy and still meet the 10% criteria.

Figure 4 illustrates the results of an analysis of the RAD_STE.DAT data. Here the resultant interference database was applied to an assumed FS system sharing spectrum with 2 GHz, 64-QAM, space diversity, digital FS routes typical of Recommendation ITU-R F.758. Using techniques described in Recommendation ITU-R PN.530, graphs depicting the cumulative effect on unavailability (the amount of time that the error ratio was less than 1 in 10^−3) were derived. The abscissa of Fig. 4 is a factor that increases unavailability of space diversity 50 hop digital routes as a result of the satellite interference. For example, about 80% of the routes experiencing interference from the satellite constellation with 24° separation would have less than a 50% increase in unavailability. This analysis gives some insight as to the apparent sensitivity of fixed digital systems and suggests that the impact on sharing be understood when changes to the definition of unavailability (i.e. ITU-T G.826) for digital systems are being considered.
Figure 5 shows the results of sharing spectrum between an assumed satellite system spaced at 60° (possibly BSS (sound) or MSS systems) and a representative fixed analogue system configuration in the 1.5 GHz band. The allowable satellite high angle pfd level is assumed to be −135 dB(W/m²) in 4 kHz. The low angle pfd was kept at −154 dB(W/m²). The high angle pfd is 9 dB higher than pfd levels in adjacent bands. The results (from RAD_RTS.DAT) indicate over 85% of the fixed systems would have less than 1 000 pW of interference for that configuration.
Figures 6 and 7 give the results of a partial study. The purpose of the study was to analyse in a quantitative manner the sensitivity of the interference distributions of the FS to changes in satellite pfd levels and to changes in the band of operation, assuming all other parameters in the sharing scenario were kept constant. The results suggest that the FS systems selected for operation in a shared environment have to be chosen with care if the same level of performance is to be maintained in all bands.

**FIGURE 6**

1.5 GHz, satellite/FS interference study
40° lat., satellite separation = 45°, pfd = dB(W/(m²/4 kHz))

**FIGURE 7**

2.5 GHz, satellite/FS interference study
40° lat, satellite separation = 45°, pfd = dB(W/(m²/4 kHz))
5. **Listing OF RAD_REL.BAS**

The following listing has been successfully compiled with a commercial compiler (Microsoft QuickBasic versions 4 and 4.5). Other compilers may require some modification of the code for proper operation. As indicated in § 1 of this Appendix, network parameters can be adjusted for both the radio-relay and satellite networks so that a variety of sharing situations can be analysed.

Care should be taken that the below numbered statements having more than one line of code be entered without control characters i.e. no “carriage return” or “line feed”.


` MAINPROGRAM
100 CLS : SCREEN 9
155 RANDOMIZE TIMER: RTS = 49:
 STS = 50# RR ROUTES, STS=# STATION SITES PER ROUTE
160 CLS : PI = 3.141593: RA = .01745329#:
 DE = 57.29578: T = 22.48309
 ' T = MAXIMUM GREAT CIRCLE LENGTH (DEG) OF ONE 50 HOP ROUTE
162 K = 6.629957: K2 = K * K: K4 = 1 / (K2 - 1) ^ .5:
 K2I = 1 / K2: PI2 = PI / 2
165 GOSUB 1650'ENTER LATITUDE OF SYSTEMS
170 GOSUB 1700'ENTER FREQUENCY
175 GOSUB 1750'ENTER RR RECEIVER NOISE TEMP
180 GOSUB 1800'ENTER RR RECEIVE MAXIMUM ANTENNA GAIN
185 GOSUB 3000'ENTER # OF RR ROUTES
190 GOSUB 4000'ENTER AMOUNT OF ORBIT AVOIDANCE
195 GOSUB 5000'ENTER SATELLITE ORBIT SEPARATION
200 GOSUB 6000'ENTER LOW/HIGH ANGLE PFD LIMIT VALUES
210 GOSUB 7000'MAKE REVISIONS OF ABOVE ENTRIES
215 PF = .005 * (PFH - PFL): PFDL = 10 ^ (.1 * PFL):
 PFDH = 10 ^ (.1 * PFH)
220 CLS : DIM A!(RTS, STS): DIM B!(1 + 2 * RTS): DIM C!(RTS, STS)
225 FOR Q = 0 TO RTS: FOR V = 0 TO STS: A(Q, V) = 0: C(Q, V) = 0:
 NEXT: NEXT
227 FOR Q = 0 TO (1 + 2 * RTS): B(Q) = 0: NEXT
230 MU = 1.6212E+18 / (FREQ ^ 2 * NTEMP)
235 MU1 = kTbl/Nc
 ' MU=Nc((c/FREQ)^2/4Pi)/kTbl, MU1 = kTbl/Nc
 ' Where:
 ' Nc=voice channel noise power
 ' = 25 picowatts
 ' c/FREQ=transmission wavelength
 ' k=Boltzmann's constant, 1.3805E-23
T = receiver noise temp. in Kelvin s
b = channel bw, 4KHz
l = feeder loss, dB

START ROUTE CALCULATIONS
FOR M = 0 TO RTS
LOCATE 13, 1: PRINT STRING$(30, 0)
LOCATE 13, 1: PRINT "CALCULATING ROUTE": M
LONGREF = T * (2 * RND - 1)
TAU = 90 * RND: TAURA = TAU * RA
TAU is the direction of RR network trendline
LATR0 = (((T / 2) * COS(TAURA)) + LATREF)
LATRO, LONGRO is latitude, longitude of the 1st RR site.
X = 319.5 + ((LONGR0 * 319.5) / (1.5 * T)):
Y = (1 - COS(TAURA)) * 77.5
X, Y = SCREEN COORDINATES FOR PLOTTING THE SITES. REMOVE ""
FROM 275, 530 - 550 FOR GRAPHIC REPRESENTATION OF ROUTES.

Find satellite horizon from 1st RR site
A = K4 * TAN(LATR0 * RA): A2 = ((1 - A * A) ^ .5) / A
AZMUTH = ATN(A2)
Azimuth = angle to horizon from south at RR point
AZ = SIN(AZMUTH) * ((1 - K2I) ^ .5)
LONGHOR = ATN(AZ / ((1 - AZ * AZ) ^ .5))
LONGHOR is the longitude difference between the RR and
horizon/orbit intercept
LONHOR = LONGHOR * DE

Calculate interference from all visible sats into a RR site
on a route.
LONGR = LONGR0: LATR = LATR0: LONS = 0
LONGR = Longitude of RR, LATR = Latitude of RR, LONS = longitude of
next visible sat.
Do the interference calculation for each site
FOR N = 0 TO STS
RR = (TAU + 25) - (50 * RND): RRD = RR * RA
RR, RRD is the pointing direction to the next site
Calculate location of next RR site
Find most easterly visible satellite.
DO WHILE LONS <= LONHOR + LONGR
LONS = LONS + SEP: LOOP
LONS = LONS - SEP
'Do the interference calculation per site.
DO WHILE LONS >= LONGR - LONHOR
GOSUB 2360

IF GAMMAW < AVOID OR GAMMAE < AVOID THEN A(M, N) = 0: C(M, N) = 0: GOTO 340

LONS = LONS - SEP: LOOP
  Calculate location of next RR site

J = LONGR: L = LATR

P = (SIN(LATR * RA)) * COS(.4496 * RA) - (COS(LATR * RA)) * (SIN(.4496 * RA)) * (COS(RRD))

Q = P / (1 - P * P) ^ .5

LATR = DE * ATN(Q) 'LATITUDE OF THE NEXT RR SITE

R = SIN(.4496 * RA) * SIN(RRD) / (1 - P * P) ^ .5:
S = R / (1 - R * R) ^ .5: DELLONGR = ATN(S) * DE

LONGR = LONGR + DELLONGR 'LONGITUDE OF NEXT RR SITE
  Calculate satellite horizon for the new RR site

A = K4 * TAN(LATR * RA): A2 = ((1 - A * A) ^ .5) / A

AZMUTH = ATN(A2)
  'Azimuth= angle to horizon from south at RR point, South reference

AZ = SIN(AZMUTH) * ((1 - K2I) ^ .5)

LONGHOR = ATN(AZ / ((1 - AZ * AZ) ^ .5))
  'LONGHOR is the longitude of the RR horizon/orbit intercept

LONGHOR = LONGHOR * DE
  Print RR route on screen

Y1 = ((L - LATR) / T) * 155: X1 = (DELLONGR / (3 * T)) * 480

LINE (X, Y)-(X + X1, Y + Y1)

FOR M = 0 TO RTS
  FOR N = 1 TO STS
    B(M) = B(M) + A(M, N)
  NEXT N
NEXT M

FOR G = 0 TO RTS
  FOR H = 0 TO STS - 1
    B(RTS + 1 + G) = B(RTS + 1 + G) + C(G, H)
  NEXT H
NEXT G

OPEN "RAD_RTS.DAT" FOR APPEND AS #1

FOR M = 0 TO 1 + (2 * RTS)
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720 'PRINT "ROUTE"; M: PRINT ";"; B(M)
725 PRINT #1, B(M)
730 NEXT
735 CLOSE #1
740 OPEN "RAD_STE.DAT" FOR APPEND AS #2
750 FOR M = 0 TO RTS: FOR N = 0 TO STS
755 A(M, N) = A(M, N) * MU1
760 PRINT #2, A(M, N): NEXT: NEXT
765 PRINT #2, 0
770 FOR M = 0 TO RTS: FOR N = 0 TO STS
775 C(M, N) = C(M, N) * MU1
780 PRINT #2, C(M, N): NEXT: NEXT
790 CLOSE #2
830 'PRINT "PROGRAM COMPLETED, PRESS ANY KEY TO END"
840 A$ = INKEY$: IF A$ = " " THEN 840
850 IF A$ = "r" OR A$ = "R" THEN LOCATE 14, 1:
855 PRINT STRING$(70, 0): GOTO 225 'REPEAT DATA BASE CALC.
860 IF A$ = "e" OR A$ = "E" THEN CLS : GOTO 1000
870 GOTO 830
1000 END ' END OF RAD_REL.BAS

'Subroutine for entering RR route latitude
1650 LOCATE 4, 1: PRINT STRING$(78, 0): LOCATE 5, 1:
1660 LOCATE 4, 1: PRINT "1) ENTER NETWORK LATITUDE (15 to 70)"
1670 INLEN% = 6: GOSUB 14000
1680 LATREF = VAL(BUFF$)
'LATREF is the latitude at the centre of the trend line
1690 IF (LATREF > 70! OR LATREF < 15!) THEN LOCATE 22, 1:
1695 RETURN

'Subroutine for entering frequency of operation
1700 LOCATE 6, 1: PRINT STRING$(78, 0): LOCATE 7, 1:
1710 LOCATE 6, 1: PRINT "2) ENTER TRANSMIT CARRIER FREQUENCY <GHz>"
1720 INLEN% = 6: GOSUB 14000
1730 FREQ = VAL(BUFF$)/FREQ = FREQUENCY OF SHARING SCENARIO IN GHZ
1740 IF FREQ <= 0! OR FREQ > 100! THEN LOCATE 22, 1:
1745 RETURN
Subroutine - enter RR receiver noise temp.

LOCATE 8, 1: PRINT STRING$(78, 0): LOCATE 9, 1:
PRINT STRING$(20, 0)

LOCATE 8, 1:
PRINT "3) ENTER AVE. VALUE OF RR RECEIVER NOISE TEMP <DEG KELVIN>"

INLEN% = 6: GOSUB 14000

NTEMP = VAL(BUFF$) 'NTEMP=NOISE TEMP OF RR RECEIVERS

IF NTEMP <= 0 THEN LOCATE 22, 1:
PRINT "OUT OF RANGE, RE-ENTER": FOR C = 1 TO 100000: NEXT:
LOCATE 22, 1: PRINT STRING$(78, 0): GOTO 1750

RETURN

Subroutine - enter RR receive antenna gain and calculate intermediate parms.

LOCATE 10, 1: PRINT STRING$(78, 0): LOCATE 11, 1:
PRINT STRING$(20, 0)

LOCATE 10, 1:
PRINT "4) ENTER MAX RADIO-RELAY RECEIVE ANTENNA DB GAIN"

INLEN% = 6: GOSUB 14000

GMAX = VAL(BUFF$) 'GMAX is MAX RR rec. Antenna gain

IF GMAX < 0 OR GMAX > 99 THEN LOCATE 22, 1:
PRINT "OUT OF RANGE, RE-ENTER": FOR C = 1 TO 100000: NEXT:
LOCATE 22, 1: PRINT STRING$(40, 0): GOTO 1800

DLAMBDA = 10 ^ ((GMAX - 7.7) / 20)
'DLAMBDA=RATIO OF REC. ANT DIA./ WAVELENGTH

G1 = 2 + 15 * (LOG(DLAMBDA) / LOG(10))
'PRINT "DLAMBDA="; DLAMBDA

PHYM = (20 / DLAMBDA) * (GMAX - G1) ^ .5

RETURN

This Subroutine to calculate RR/sat elevation and separation angles and interference

W = (LONS - LONGR):

ASAT = ATN((TAN(W * RA)) / SIN(LATR * RA)): ASAT1 = ASAT

ASAT=AZMUTH ANGLE TO SUBSAT REFERENCED TO SOUTH

U = COS(LATR * RA) * COS(W * RA):

OMEGA = ATN(SIN(BETA) / (K - COS(BETA)))

THETAR = PI2 - (OMEGA * DE)

THETA = THETAR * DE

THETA= ELEVATION ANGLE TO SAT FROM RR

VW = (COS(THETAR)) * COS(ASAT - RRD):

GAMMAW = (PI2 - ATN(VW/SQR (1 - VW * VW)) * DE

GAMMAW = ANGLE BETWEEN SATELLITE AND WEST POINTING RECEIVER

GAMMAE = 180 - GAMMAW

GAMMAE = ANGLE BETWEEN SATELLITE AND EAST POINTING RECEIVER

IF GAMMAW < 0 THEN GAMMAW = 180 + GAMMAW

IF GAMMAE < 0 THEN GAMMAE = 180 + GAMMAE
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2430 IF (GAMMAW <= AVOID) OR (GAMMAE <= AVOID) THEN RETURN
2440 IF THETA >= 0 AND THETA < 5 THEN PFD = PFDL: GOTO 2500
2450 IF THETA >= 5 AND THETA < 25 THEN
PFD = (10 ^ (PFL * .1 + PF * (THETA - 5))): GOTO 2500
2460 IF THETA >= 25 THEN PFD = PF DH
2500 IF GAMMAW >= 0 AND GAMMAW <= PHYM THEN GTHETAW
= 10 ^ (.1 * (GMAX - .0025 * (DLAMBDA * GAMMAW) ^ 2)): GOTO 2540
2510 IF GAMMAW >= PHYM AND GAMMAW < (100 / DLAMBDA) THEN
GTHETAW = 10 ^ (.1 * G1): GOTO 2540
2520 IF GAMMAW >= (100 / DLAMBDA) AND GAMMAW < 48 THEN
GTHETAW = 10 ^ (.1 * (52 - 10 * (LOG(DLAMBDA)) / LOG(10) -
25 * (LOG(GAMMAW)) / LOG(10))): GOTO 2540
2530 IF GAMMAW >= 48 AND GAMMAW <= 180 THEN
GTHETAW = 10 ^ (1 - (LOG(DLAMBDA)) / LOG(10))
2540 SINTW = MU * PFD * GTHETAW:
IF N > 0 THEN A(M, N) = A(M, N) + SINTW
'SINTW = INTERFERENCE INTO WEST POINTING RECEIVERS
2550 IF GAMMAE >= 0 AND GAMMAE <= PHYM THEN GTHETA E
= 10 ^ (.1 * (GMAX - .0025 * (DLAMBDA * GAMMAE) ^ 2)): GOTO 2590
2560 IF GAMMAE >= PHYM AND GAMMAE < (100 / DLAMBDA) THEN
GTHETA E = 10 ^ (.1 * G1): GOTO 2590
2570 IF GAMMAE >= (100 / DLAMBDA) AND GAMMAE < 48 THEN
GTHETA E = 10 ^ (.1 * (52 - 10 * (LOG(DLAMBDA)) / LOG(10) -
25 * (LOG(GAMMAE)) / LOG(10))): GOTO 2590
2580 IF GAMMAE >= 48 AND GAMMAE <= 180 THEN
GTHETA E = 10 ^ (1 - (LOG(DLAMBDA)) / LOG(10))
2590 SINTE = MU * PFD * GTHETA E: IF N < 50 THEN
C(M, N) = C(M, N) + SINTE
'SINTE = INTERFERENCE INTO EAST POINTING RECEIVERS
2600 RETURN

'Subroutine - ALLOWS ENTRY OF # RR ROUTES (RTS)
3000 LOCATE 12, 1: PRINT STRING$(78, 0): LOCATE 13, 1:
PRINT STRING$(20, 0)
3010 LOCATE 12, 1:
PRINT "5) ENTER NUMBER OF RADIO-RELAY ROUTES <300 MAX>"
3020 INLEN% = 3: GOSUB 14000
3030 RTS = VAL BUFFS
3033 IF RTS > 300 OR RTS < 1 THEN LOCATE 22, 1:
PRINT "Out of Range, RE-ENTER": FOR C = 1 TO 100000: NEXT:
LOCATE 22, 1: PRINT STRING$(40, 0): GOTO 3000
3035 IF RTS <= 300 THEN RTS = RTS - 1: RETURN
'Subroutine to specify orbit avoidance

4000    LOCATE 14, 1: PRINT STRING$(78, 0): LOCATE 15, 1: PRINT STRING$(20, 0)
4040    LOCATE 14, 1: PRINT "6) ENTER ORBIT AVOIDANCE ANGLE, DEG. <ENTER>"
4050    INLEN% = 4: GOSUB 14000
4060    AVOID = VAL(BUFF$)
4070    IF AVOID < 0 THEN LOCATE 22, 1: PRINT "Out of Range, RE-ENTER": FOR C = 1 TO 100000: NEXT: LOCATE 22, 1: PRINT STRING$(40, 0): GOTO 4000
4080    RETURN

'Subroutine to determine satellite orbit separation

5000    LOCATE 16, 1: PRINT STRING$(78, 0): LOCATE 17, 1: PRINT STRING$(20, 0)
5010    LOCATE 16, 1: PRINT "7) ENTER SATELLITE ORBIT SEPARATION (2 MIN), DEG. <ENTER>"
5060    INLEN% = 5: GOSUB 14000
5070    SEP = VAL(BUFF$)
5080    IF SEP < 2 THEN LOCATE 22, 1: PRINT "Out of Range, RE-ENTER": FOR C = 1 TO 100000: NEXT: LOCATE 22, 1: PRINT STRING$(40, 0): GOTO 5000
5090    RETURN

'Subroutine - Enter low/high angle pfd value

6000    LOCATE 18, 1: PRINT STRING$(78, 0): LOCATE 19, 1: PRINT STRING$(20, 0): LOCATE 20, 1: PRINT STRING$(78, 0): LOCATE 21, 1: PRINT STRING$(20, 0)
6010    LOCATE 18, 1: PRINT "8A) ENTER MAXIMUM LOW ANGLE (0 <= THETA < 5°) PFD LEVEL"
6020    INLEN% = 5: GOSUB 14000
6030    PFL = VAL(BUFF$)
6040    IF PFL > 0 THEN LOCATE 22, 1: PRINT "OUT OF RANGE, ENTER NEGATIVE VALUE": FOR C = 1 TO 100000: NEXT: LOCATE 22, 1: PRINT STRING$(50, 0): GOTO 6000

' - Enter high angle pfd value

6050    LOCATE 20, 1: PRINT STRING$(78, 0): LOCATE 21, 1: PRINT STRING$(20, 0)
6050    LOCATE 20, 1: PRINT "8B) ENTER MAXIMUM HIGH ANGLE ( THETA >= 25°) PFD LEVEL"
6020    INLEN% = 5: GOSUB 14000
6030    PFH = VAL(BUFF$)
IF PFH > 0 THEN LOCATE 22, 1:
PRINT "OUT OF RANGE, ENTER NEGATIVE VALUE":
FOR C = 1 TO 100000: NEXT: LOCATE 22, 1: PRINT STRING$(50, 0):
GOTO 6500

PF = .005 * (PFH - PFL): PFDL = 10 ^ (.1 * PFL):
PFDH = 10 ^ (.1 * PFH)
RETURN

LOCATE 22, 1: PRINT STRING$(78, 0): LOCATE 23, 1:
PRINT STRING$(20, 0)

LOCATE 22, 1:
PRINT "REVISIONS? ENTER '1 - 8' OR '0' IF NONE "

A$ = INKEY$: IF A$ = "" THEN 7020
IF A$ = "0" OR A$ = CHR$(13) THEN RETURN
IF A$ = "1" THEN GOSUB 1650: GOTO 7000
IF A$ = "2" THEN GOSUB 1700: GOTO 7000
IF A$ = "3" THEN GOSUB 1750: GOTO 7000
IF A$ = "4" THEN GOSUB 1800: GOTO 7000
IF A$ = "5" THEN GOSUB 3000: GOTO 7000
IF A$ = "6" THEN GOSUB 4000: GOTO 7000
IF A$ = "7" THEN GOSUB 5000: GOTO 7000
IF A$ = "8" THEN GOSUB 6000: GOTO 7000
GOTO 7000

'Subroutine for entering numeric data

TRUE = -1: FALSE = 0
Formated numeric input subroutine

POINT. = FALSE: DEC.CNT = 0: BUFF$ = " ":
ERAS$ = CHR$(29) + CHR$(95) + CHR$(29):
PRINT STRING$(INLEN%, CHR$(95)); STRING$(INLEN%, CHR$(29));

W$ = INPUT$(1): IF W$ >= "0" AND W$ <= "9" THEN 14100
IF W$ <> CHR$(8) THEN 14040
IF W$ = "." THEN POINT. = FALSE: DEC.CNT = 0
IF POINT. THEN DEC.CNT = DEC.CNT - 1: GOTO 14100
IF W$ = CHR$(8) THEN 14040
IF BUFF$ = "" THEN 14100 ELSE W$ = RIGHTS(BUFF$, 1):
BUFF$ = LEFTS(BUFF$, LEN(BUFF$) - 1): PRINT ERAS$;
IF W$ = "." THEN POINT. = FALSE: DEC.CNT = 0
IF W$ = "." THEN 14100 ELSE IF LEN(BUFF$) = INLEN% THEN 14100 ELSE POINT. = TRUE: GOTO 14100
IF W$ = "." OR W$ = "+" THEN IF BUFF$ > " " THEN 14100 ELSE 14100
GOTO 14100

IF LEN(BUFF$) = INLEN% OR DEC.CNT = 3 THEN
14100 ELSE PRINT WS$; : BUFF$ = BUFF$ + WS$:
IF POINT. THEN DEC.CNT = DEC.CNT + 1: GOTO 14100 ELSE 14100
Subroutine - Enter alphanumeric data (not used)

14300  BKSPC$ = CHR$(8):  CR.RET$ = CHR$(13):
       ERAS$ = CHR$(29) + " " + CHR$(29) 'String input routine

14305  BUFF$ = " "

14310  W$ = INPUT$(1):  IF W$ >= "a" AND W$ <= "z" THEN
       W$ = CHR$(ASC(W$) - 32):  GOTO 14350

14315  IF W$ >= " " AND W$ <= CHR$(127) THEN 14350

14320  IF W$ = BKSPC$ THEN IF BUFF$ = " " THEN 14310 ELSE
       BUFF$ = LEFT$(BUFF$, LEN(BUFF$) - 1):  PRINT ERAS$; :
       GOTO 14310

14340  IF W$ = CR.RET$ THEN RETURN ELSE 14310

14350  IF LEN(BUFF$) = INLEN% THEN 14310 ELSE PRINT W$; :
       BUFF$ = BUFF$ + W$:  GOTO 14310