CHAPTER 5. NETWORK DESIGN

Network design is the essence of spectrum management. It translates coverage proposals into transmitter specifications and ensures that the reception of the wanted transmission is adequately free from noise and interference. The design requires the determination of two important parameters namely: the service area and coverage area.

The coverage area is defined as a part of service area which is protected against interference for a specified percentage of time, whereas service area is defined as the area which it is desired to cover and within which the level of wanted signal exceeds some minimum value, usually set by noise considerations.

The design of the system must also satisfy the following three independent constraints.

SERVICE AREA LIMITATIONS: The boundaries within which the communication must take place.

MINIMUM SIGNAL QUALITY CRITERIA: Received Signal level corresponding to a minimum acceptable grade of service.

RELIABILITY: The probability of communication expected by
the mobile radio station at any location when it is
desired to communicate.

Within the frame work of these constraints, the system has to
be designed. The physical parameters which must be
considered are terrain roughness, degree of urbanisation,
frequency band and RF protection ratio's against interference
[28]. The trade off's available are number of variable
system parameters such as antenna height, system gains,
system losses and station locations.

If it is supposed that the available frequency band is
channelised, then it is desired to derive the number of
channels that are required to cover the total area. As this
number is obviously finite, sooner or later, at some distance
from the starting point, this channel has to be reused. The
smaller the distance between two transmitters operating on
the same channel, lower is the number of channels required.
But it is required that the separation should be long enough
for the two co-channel transmitters not to interfere with
each other.

Thus the optimum number of channels required are determined
by the action radii and the coverage efficiency of the
network designed.
5.1 CELL PARAMETERS

The idea being explained is that of a regular lattice [45] with interfering transmitters being situated at a uniform distance from a given, wanted, transmitter. If in the network design this uniformity is maintained then all service areas will experience similar conditions of service and interference. With this approach a network can be designed for a relatively large area. However, a starting point in this process is to define the geometrical parameters and optimise these parameters to provide optimum area coverage with limited frequency channels.

As already explained in chapter 4 the array of fixed station sites can be approximated by a regular lattice model. The service zones of these stations cover the total area, but the model is based on non-overlapping hexagonal cells.

The primary lattice with hexagonal cells has a regular triangular pattern fully described by the lattice module M, which is defined as the closest spacing between adjacent fixed stations. The area of one hexagonal cell is equal to:
\[ A = \left(\frac{1}{2}\right) \sqrt{3} R \]  

(5.1)

The coverage criterion in the triangular lattice requires:

\[ M \leq \sqrt{3} R \]  

(5.2)

Assume that the network size is large enough to call for a regular plan of frequency reuse. With regard to compatibility criterion the secondary lattice of co-channel stations must also be regular. In fact it is triangular too and \( D \) is the modulus of the co-channel lattice. \( D \) is defined as the closest spacing between co-channel fixed stations. Fig. 5.1 describes a regular lattice model of the point to area network.

The cluster of cells is a closed group of \( N \) contiguous primary hexagons with different frequency assignments. Within the regular lattice, each cluster contains the same set of \( N \) frequency channels. Thus the entire network is utilizing the same \( N \) re-used frequency channels (or channel sets when more channels per station are used).

Refer to the Fig. 5.1, note that the cluster boundary is a broken line formed by the sides of the elementary hexagon. When rectified this boundary also forms a regular hexagon with side length equal to the \( D / \sqrt{3} \).
Fig. 5.1: CELL PARAMETERS: REGULAR LATTICE (N = 7)
The area of the hexagon is now equal to \((1/2) \sqrt{3} D^2\).

On the other hand, the territory subdivision principles requires that exactly the same area be covered by one cluster composed of \(N\) cells. We thus have:

\[
N \cdot \frac{2}{(1/2)} \sqrt{3} m = \frac{2}{(1/2)} \sqrt{3} D^2
\]

or \(D = m \sqrt{N}\) \hspace{1cm} (5.3)

The formula holds exactly for any regular triangular lattice composed of hexagonal cells and quasi hexagonal cluster. In the above equation the two geometric continuous variables \(m\) and \(D\) are related to the spectral parameter \(N\), which has to be a positive integer.

Full regularity of the lattice (45) is obtained only when \(N\) is given by the equation:

\[
N = k + 1 + 11
\]

\[
\begin{array}{c}
K \geq 1 \\
1 \geq 0
\end{array}
\hspace{1cm} \text{Natural numbers}
\]

Hence the sequence of admissible \(N\) is

\[
\text{Nad} = 3, 4, 7, 9, 12, 13, 16, 19, 21, 25
\]

\hspace{1cm} (5.5)
With $N = N_{ad}$, the regular lattice exhibits only one co-ordination distance given by equation (5.3). The pattern of channel assignments is then characterised by regular buffer rings composed of cells in which the frequency of the cell in the centre of the ring can not be utilised.

The choice of $N_{ad} = 2\ (k = 1, l = 1)$ or $4\ (k = 2, l = 0)$ would correspond to the one ring structure, not employed in practice. The two rings are obtained with $N = 7\ (k = 2, l = 1)$ or $N = 9$ and three rings with $N = 12\ (k = 2, l = 2)$. The cluster with $N = 16$ or $N = 19$ channels exhibits four buffer rings. Fig. 5.2 describes typical ring structures.

5.1.1 OPTIMISATION OF PARAMETERS

If in a very special application, all fixed stations are identical, the co-channel compatibility criterion (equation 4.17) is valid throughout. In view of equation (5.3), we have:

$$M \geq (R + R_i)$$

So that

$$M \geq (R + R_i) / \sqrt{N}$$

(5.6)
Fig. 5.2: TYPICAL RING STRUCTURES
As \( R \) and \( R_i \) are constants dependent on the equipment and on the propagational data, the maximum modulus length \( M_{\text{max}} \), resulting from equation (5.2) is also constant but \( M_{\text{min}} \) given by equation (5.6) can be decreased by increasing \( N \), i.e., at the cost of the spectrum occupancy. In actual design, the displacement of fixed stations can not follow the regular lattice model. Then the available interval for \( M \) is the measure of the lattice deformability.

It follows from equation (5.2) and (5.6) that the interval for \( M \) is given by:

\[
(R + R_i) / \sqrt{N} \leq M \leq \sqrt{3}R
\]  
(5.7)

The solution for \( M \) exists only if

\[
\sqrt{3}R \geq (R + R_i) / \sqrt{N}
\]

which is not a priori satisfied with a fully regular lattice, the lowest number of channels which would theoretically ensure compatible frequency reuse would be:

\[
N_{\text{min}} = \frac{2}{3R} (R + R_i)
\]  
(5.8)

but \( \Delta M \) interval then reduce to zero. When \( N \leq 9 \) adjacent
channels can not be avoided in the adjacent stations. Then the
compatibility with respect to the adjacent
channels has to be achieved by satisfying the criterion
(equation 4.18). The closest spacing of adjacent channel
stations is shown in Fig. 5.3 and this leads to the
relation:

\[ M \geq (R + Ra) \]  \hspace{1cm} (5.9)

The figure describes the available variation of lattice
modulus \( M \), as affected by the number of cells \( N \), in one
cluster. The hatched area marks the region of admissible
solutions for \( M \), depending upon the action radii of the
stations.

This is an additional lower bound on modulus. It follows
that an optimum choice of \( N \) exists in this case. A
straight combination of equation (5.7) and (5.9) yields
theoretical minimum number of channels \( N^{\text{opt}} \) ensuring
the full \( \Delta M \) lattice distortion interval we arrive at:

\[ N^{\text{opt}} = \left( \frac{R + Ri}{R + Ra} \right)^2 \]  \hspace{1cm} (5.10)

The actual choice of \( N^{\text{opt}} \) for a regular network lattice is
usually the smallest admissible \( N \) ad from the set given by
Fig. 5.3: Variations of Lattice Modulus $M$
equation (5.5) exceeding $N^{\text{opt}}$. The maximum value of $\Delta M$ interval is then (if $N < 12$):

$$\Delta M_{\text{max}} = (\sqrt{3}-1)R - Na$$

(5.11)

This interval can be increased at the cost of increasing the spectrum occupancy by using $N \geq 12$. The extra advantage gained with larger values of $N$, whether from the sequence of admissible numbers or not is the increase in co-ordination distance.

Since $D \leq V N$ the risk of co-channel interface can be diminished in that way.

However, in order to obtain best use of the spectrum it is desirable to avoid unnecessary coverage overlaps between adjacent transmitters. The network design can be optimised by reducing the total interference into the service area by the judicious selection of locations for co-channel and adjacent channel transmitters.
5.2 ACTION RADII

In a communication network the service radius and interference radii depend on the system parameters and the radio propagation loss between the transmitting and receiving antennas. These are computed for given percentage of location and time probability.

It has been explained earlier that diffraction of radio waves is responsible for communication beyond horizon. At distances just beyond the radio horizon, diffraction becomes the dominant mode of propagation. As the distance increases still further, a new mode of propagation, the tropospheric scatter, appears and enhance the signal over the pure diffraction region.

Thus for communication beyond horizon, the propagation loss is supplemented by a transhorizon correction factor $\Delta L$ which is a function of frequency $f_0$ and distance $d$. The value of $\Delta L$ can be approximated by a comprehensive set of formulae.

LOW MODEL

\[
\Delta L = 40 \log \left( \frac{(d + \Delta d)/d}{10} \right)
\]

(5.12)

For $df \leq d \leq d_0$
NETWORK DESIGN

\[ \Delta l = 20 \log \left( \frac{(d + \Delta d)/d}{10} + 0.62M\Delta d \right) \]  
(5.13)

For \( d_1 \leq d \leq d_2 \)

HIGHT MODEL

\[ \Delta l = 20 \log \left( \frac{(d + \Delta d)/d}{10} \right) \]  
(5.14)

For \( d \leq d_1 \)

\[ \Delta l = 20 \log \left( \frac{(d + \Delta d)/d}{10} \right) + 50(\Delta d/\Delta d_1) \]  
(5.15)

For \( d_1 \leq d \leq d_2 \)

The parameters \( M, \Delta d, d_1, \text{ and } d_2 \) are calculated by using empirical formulae described in section 2.6 of chapter 2.

5.2.1 SERVICE RADIUS

The service radius is conventionally deduced from the median value of propagation loss. The median loss value lies between the transmitted power level \( (Pt_{St})/Lt \) and the minimum useable received signal level \( (Prs_{Lr})/Gr \).

A correction to the service radius is required when calculated service radius \( R \) is greater than radio horizon distance \( dh \).
5.2.2 INTERFERENCE RADII

From the path loss versus distance relationship and value of co-channel protection ratio, one can derive the minimum separation distance between two co-channel transmitters to achieve adequate mutual protection.

However, the problem of the co-channel interference radius Ri is much more complicated because it is based on the worst case approach. This is defined as the maximum distance beyond which interference free reception of the weakest desired signal is ensured most of the time.

It is usually a requirement that a service be protected against interference for a high percentage of time. Figure of 90% is being in use in different communication networks.

Thus the interfering levels which can exist for 10% of the time must be calculated. These are invariably higher than the values appropriate for 90% of the time. However, the protection ratios adopted for small time percentages are usually lower than those for continuous interference.

This is because it is considered not unreasonable to expect listeners to accept a lower grade of service for a small percentage of time. The complication introduced
into planning is that one must calculate the value of interfering field strength plus appropriate protection ratios for a smaller value of time (90%) for the service being planned.

The co-channel protection ratio $P_{BC}$ determines the spacing between the median value of the desired signal $L(50)$ curves and the upper decile value of the interference determined from $L(10)$ curves.

The adjacent channel interference radius $R_a$ is determined by the adjacent channel protection ratio $P_{Ra}$. The value of $R_a$ is usually found within the horizon.

5.3 ALGORITHM NETWORK DESIGN

The network design follow logically from the analysis of the action radii as affected by radio propagation, and the network parameters as affected by the compatibility criteria. The design described is based on the following assumptions:

a) All transmitters are identical i.e. their power and antenna heights are the same.

b) They are equipped with non-directional antennas.

To begin with, the following parameters of the system must
be known: Pt. St. ht. hr. Gr. ht. hr. Pr. Prs and the co-channel and adjacent channel protection ratios. Correction to the range will have to be applied when service radius obtained is greater than the radio line of sight distance dh.

First of all the service radius is calculated. Then the interference radii are determined. This is followed by determination of network parameters. With proper action radii known, the parameters M, N and D are determined for the network. Detailed flow charts for the design are reported in Section 5.3.1 and the complete programme listing is reproduced in Section 5.3.2.

5.3.1 FLOW CHARTS

The total design is described by the following flow charts:

a) SERVICE RADIUS PREDICTION
b) RADIO HORIZON CALCULATIONS
c) RANGE PREDICTION
d) RANGE CORRECTION
e) ITERATION CALCULATIONS
f) CO-CHANNEL INTERFERENCE RADIUS
g) ADJACENT CHANNEL INTERFERENCE RADIUS
h) NETWORK PARAMETERS

These are described in Figure 5.4 to Figure 5.11.
Fig. 5.4: SERVICE RADIUS PREDICTION

START

INPUT SYSTEM PARAMETERS

CALCULATE RADIO HORIZON $d_h$

CALCULATE ALLOWABLE LOSS $L$

APPLY CORRECTION TO ANT HEIGHTS

CALCULATE SERVICE RADIUS $R$

CHECK $R > d_h$

NO

PRINT SERVICE RADIUS $R$

YES

APPLY RANGE CORRECTION

PRINT SERVICE RADIUS $R$

STOP
Fig. 5.5: RADIO HORIZON CALCULATIONS
Fig. 5.6: RANGE PREDICTION

SUBROUTINE TO CALCULATE RANGE

SPECIFY LOCATION PROBABILITY

SPECIFY TERRAIN

SPECIFY AREA

CALCULATE RANGE, R

CHECK
$R > d_h$

NO

PRINT $P_x$

PRINT TERRAIN

PRINT AREA

YES

CALCULATE LOSS AT $d_h, L_{d_h}$

RETURN
Fig. 5.7: RANGE CORRECTION

```
SUBROUTINE RANGE CORRECTION

CALCULATE Ldiff (L - Ldh)

LET d = dh

INCREMENT d
   d = d + Δd

FIND ΔL FOR Δd

CHECK ΔL ≥ Ldiff
   NO

CHECK ΔL = Ldiff
   NO
      LET d = d - Δd
   YES

CORRECTED RANGE R = d

RETURN

Ldiff = Ldiff - ΔL

NO
```

Fig. 5.7: RANGE CORRECTION
Fig. 5.8: ITERATION CALCULATIONS

1. **COROUTINE TO CALCULATE ΔL**
2. **CALCULATE d₁ d₂ dcf AND dc**
3. **CHECK d > dc**
   - **NO**: **CALCULATE L₁ USING EQ. 2.60**
   - **YES**: **CALCULATE L₁ USING EQ. 2.61**
4. **CHECK d > d₁**
   - **NO**: **CALCULATE L₂ USING EQ. 2.54**
   - **YES**: **CALCULATE L₂ USING EQ. 2.55**
5. **NO**: **CHECK d > d₁**
6. **CHECK L₁ > L₂**
   - **YES**: **CALCULATE ΔL USING EQ. 5.15**
   - **NO**: **CALCULATE ΔL USING EQ. 5.14**
7. **CHECK d > dc**
   - **NO**: **CALCULATE ΔL USING EQ. 5.12**
   - **YES**: **CALCULATE ΔL USING EQ. 5.13**
8. **RETURN**
Fig. 5.9: CO-CHANNEL INTERFERENCE RADIUS
Fig. 5.10: ADJACENT CHANNEL INTERFERENCE RADIUS
START

SPECIFY SERVICE RADIUS, Rx

SPECIFY INTERFERENCE RADIUS, Ri

SPECIFY INTERFERENCE RADIUS, Ra

CALCULATE LATTICE MODULUS, M min. & M max.

CALCULATE NUMBER OF CELLS N min., N & N opt.

N < 12

YES

CALCULATE CO-ORDINATION DISTANCE, D min.(M min.)

CALCULATE CO-ORDINATION DISTANCE, D max.(M max.)

PRINT M min., M max., D min., D max. AND N min.

STOP

NO

N > N min.

M < M max.

CALCULATE D max.

PRINT N min, M max. AND D max.

Fig. 5.11: NETWORK PARAMETERS
5.3.2 Programme: Optimum Area Coverage

Programme Listing

100 REM
110 REM * MOBILE RADIO COMMUNICATION SYSTEM *
120 REM
130 REM * * MAIN PROGRAM * *
140 REM
150 REM
160 LPRINT TAB(60):"Page No 1"
170 LPRINT: "PROGRAMME LISTING"
180 LPRINT TAB(25):"OPTIMUM AREA COVERAGE"
190 LPRINT TAB(25):"WITH LIMITED RADIO CHANNELS"
200 LPRINT TAB(25):"SERVICE RADIUS PREDICTION"
210 LPRINT: "*
220 REM
230 REM *
240 REM *
250 REM
260 REM * INPUT SYSTEM PARAMETERS *
270 REM
280 LPRINT TAB(12):"1. SYSTEM PARAMETERS"
290 LPRINT
300 GOSUB 1300
310 REM * CALCULATE RADIO HORIZON *
320 REM
330 LPRINT TAB(12):"2. RADIO HORIZON"
340 LPRINT
350 GOSUB 1670
360 REM * CALCULATE SERVICE RADIUS *
370 REM
380 LPRINT TAB(12):"3. SERVICE RADIUS"
390 LPRINT
400 REM * CALCULATE ALLOWABLE PATH LOSS *
410 REM
420 GOSUB 2170
430 REM * CALCULATE RANGE *
440 REM
450 GOSUB 2390
460 LET R=D
470 PRINT TAB(15):"PREDICTED RANGE, R = ":R:"
480 PRINT
490 REM * CHECK IF CORRECTION TO RANGE IS REQUIRED *
500 IF D<K THEN 550
510 REM * CALCULATE RANGE CORRECTION *
520 REM
NETWORK DESIGN

330 GOSUB 3370
340 LET R=0
350 LPRINT TAB(15);"SERVICE RADIUS, R =";R;"Kms."
360 LPRINT
370 LET SP=SM+PMS
380 LPRINT TAB(15);"SYSTEM PERFORMANCE MARGIN =";SP;"K"
390 LPRINT:LPRINT
400 REM CHANGE PAPER ROUTINE
410 PRINT:LPRINT
420 PRINT "Press (P) To Continue."
430 CMD$ = INKEY$:IF CMD$ = "" THEN 630
440 IF CMD$ <> "P" AND CMD$ <> "Q" THEN 630
450 LPRINT:LPRINT
460 LPRINT TAB(50);"Page No 2"
470 LPRINT:LPRINT
480 REM ********************************************************************
490 REM * INTERFERENCE RADIUS PREDICTION *
500 REM ********************************************************************
510 REM * CALCULATE CO-CHANNEL INTERFERENCE RADIUS *
520 REM ********************************************************************
530 LPRINT TAB(12);"4. INTERFERENCE RADIUS"
540 PRINT
550 PRINT "CO-CHANNEL INTERFERENCE RADIUS CALCULATIONS"
560 LPRINT
570 LPRINT TAB(15); "4.1 CO-CHANNEL INTERFERENCE RADIUS"
580 LPRINT
590 REM * CALCULATE ALLOWABLE PATH LOSS *
600 REM ************************************************************
610 GOSUB 4220
620 REM CALCULATE CO-CHANNEL INTERFERENCE RADIUS
630 GOSUB 4470
640 REM SELECT LOWER VALUE
650 IF DLOW<DHIG THEN 890
660 LET RI=DHG
670 GOTO 900
680 LET RI=DLOW
690 LPRINT TAB(20);"INTERFERENCE RADIUS CO-CHANNEL, Ri =";RI;"Kms."
700 LPRINT
710 PRINT
720 REM * CALCULATE ADJACENT CHANNEL INTERFERENCE RADIUS *
730 REM ********************************************************************
740 REM ********************************************************************
750 PRINT "ADJACENT CHANNEL INTERFERENCE RADIUS CALCULATIONS"
760 LPRINT
770 LPRINT TAB(15); "4.2 ADJACENT CHANNEL INTERFERENCE RADIUS"
NETWORK DESIGN

* CALCULATE ALL-COMMUNICATIONS PATH LOSS *

* CALCULATE ADJACENT CHANNEL INTERFERENCE RADIUS *

* TRANSMITTER PARAMETERS *
* POWER, FC *(W)*, FC *
* ANTENA gain *(dB)*, GI*
* FILTER *(dB), F* *
* DIRECTIONAL LENS, LENS *(dB), LC*
* COAX, C, FC *
* CAT 5, CAT 6, CAT 7 *

* RECEPTOR PARAMETERS *
* POWER, PH *(W)*, PH *
* GI *
NETWORK DESIGN

1430 LPRINT USING IMG1#:"Tx ANTENNA GAIN =".GT."dB"
1440 LPRINT USING IMG1#:"Tx ANTENNA HEIGHT =".HT."m"  
1450 LPRINT USING IMG1#:"Rx LOSSES =".LT."dB"
1460 LPRINT TAB(15):"(COMBINER + FILTER + CABLE)"
1470 PRINT
1480 REM * RECEIVER PARAMETERS *
1490 INPUT "Rx SENSITIVITY.Prs(dBm)";PRS  
1500 INPUT "Rx ANTEENA HEIGHT.hr (m)";HR  
1510 INPUT "Rx ANTENNA GAIN.Gr (dB)";GR  
1520 PRINT "Rx LOSSES.Lr (dB)"
1530 INPUT "(CABLE + DUPLEXER + FILTER)";LR
1540 LPRINT USING IMG1#:"Rx SENSITIVITY =".PRS."dBm"
1550 LPRINT USING IMG1#:"Rx ANTEENA HEIGHT =".HR."m"
1560 LPRINT USING IMG1#:"Rx ANTENNA GAIN =".GR."dB"
1570 LPRINT USING IMG1#:"Rx LOSSES =".LR."dB"
1580 LPRINT TAB(15):"(CABLE + DUPLEXER + FILTER)"
1590 PRINT
1600 REM * SYSTEM MARGIN *
1610 INPUT "SYSTEM MARGIN. SM (dB)";SM
1620 LPRINT
1630 LPRINT USING IMG1#:"SYSTEM MARGIN =".SM."m",SM."dB"
1640 PRINT;PRINT  
1650 LPRINT;LPRINT
1660 RETURN
1670 REM * SUBROUTINE NO. 2 (RADIO HORIZON CALCULATION) *
1680 REM * SUBROUTINE NO. 2 (RADIO HORIZON CALCULATION) *
1690 LET LGC=LOG(10)
1700 REM * SPECIFY SURFACE TO SELECT APPROPRIATE FORMULA *
1710 PRINT "SPECIFY SURFACE : ENTER 1.2.3.4 OR 5"  
1720 PRINT "1 FOR SEA WATER"
1730 PRINT " 1 FOR MARSHY LAND"
1740 PRINT " 2 FOR AVERAGE LAND"
1750 PRINT " 3 FOR PLAINS"
1760 PRINT " 4 FOR DESERTS"
1770 PRINT " 5 FOR DESERTS"
1780 PRINT
1790 INPUT "SURFACE":SR
1800 ON SR GOTO 1810,1850,1890,1930,1970
1810 REM CALCULATE CORRECTION FACTOR FOR SEA WATER
1820 LPRINT TAB(15):"SURFACE : SEA WATER"
1830 LET HA=10^-((-2.1/LGC)*LOG(FC)+5.34)
1840 GOTO 2000
1850 REM CALCULATE CORRECTION FACTOR FOR MARSHY LAND
1860 LPRINT TAB(15):"SURFACE : MARSHY LAND"
1870 LET HA=10^-((-1.6/LGC)*LOG(FC)+5.45)
1880 GOTO 2000
NETWORK DESIGN

1890 REM CALCULATE CORRECTION FACTOR FOR AVERAGE LAND
1900 LPRINT TAB(15):"SURFACE : AVERAGE LAND"
1910 LET HA=10^((−1.33/LGC)^LOG(FC)+2.74);
1920 GOTO 2000
1930 REM CALCULATE CORRECTION FACTOR FOR PLAINS
1940 LPRINT TAB(15):"SURFACE : PLAINS"
1950 LET HA=10^((−1.33/LGC)^LOG(FC)+2.68);
1960 GOTO 2000
1970 REM CALCULATE CORRECTION FACTOR FOR DESERTS
1980 LPRINT TAB(15):"SURFACE : DESERTS"
1990 LET HA=10^((−1.33/LGC)^LOG(FC)+2.61);
2000 REM CALCULATE RADIO HORIZON FOR SPECIFIED SURFACE
2010 PRINT
2020 PRINT "ANTENNA CORRECTION FACTOR, na =";HA;"m"
2030 IF 10*(HT*HR)<(HA^2) THEN 2090
2040 IF (HT*HR)−10*(HA^2) THEN 2110
2050 H1=SGR((HT^2)+(HA^2))
2060 H2=SGR((HR^2)+(HA^2))
2070 LET DH=4*(SGR(H1)+SGR(H2))
2080 GOTO 2120
2090 LET DH=S(SGR(HA))
2100 GOTO 2120
2110 LET DH=4*(SGR(HT)+SGR(HR))
2120 DH = (INT(DH^1000))/1000
2130 LPRINT
2140 LPRINT TAB(15):"RADIO HORIZON DISTANCE, dh =";DH;"Kms."
2150 LPRINT+LPRINT
2160 RETURN
2170 REM ******************************************************
2180 REM * SUBROUTINE NO. 3 (ALLOWABLE PATH LOSS) *
2190 REM ******************************************************
2200 REM * SPECIFY PROBABILITY OF COMMUNICATION *
2210 PRINT
2220 INPUT "PROBABILITY OF COMMUNICATION P(P%) :";PX
2230 LPRINT TAB(15):"PROBABILITY OF COMMUNICATION, P :";PX;"%"
2240 LPRINT
2250 IF PX<50 THEN PME=−2.338+.076*PX−(3.202/LGC)*LOG(PX))
2260 IF PX>50 THEN PME=1.638+.076*PX−(3.202/LGC)*LOG(100−PX))
2270 IF PX=50 THEN PME=0
2280 LET PR=PM+PMS
2290 PRINT
2300 PRINT "RECEIVED SIGNAL LEVEL, Pr :";PR;"dBm"
2310 LET L=PT−LT+GR−LR−PR−SM
2320 RETURN
NETWORK DESIGN

2330 REM **************************************************************************
2340 REM  * SUBROUTINE NO. 4 (RANGE PREDICTION)  *
2350 REM **************************************************************************
2360 REM  * EQLI MODEL IS USED FOR ROLLING TERRAIN  *
2370 REM  * OKUMURA MODEL IS USED FOR QUASI-SMooth TERRAIN  *
2380 PRINT
2390 PRINT "SPECIFY TERRAIN : ENTER 1 OR 2"
2400 PRINT "   1 FOR ROLLING TERRAIN"
2410 PRINT "   2 FOR QUASI-SMooth TERRAIN"
2420 INPUT "TERRAIN":TR
2430 PRINT
2440 ON TR GOTO 2450,2500
2450 REM  * USE EQLI MODEL FOR ROLLING TERRAIN  *
2460 LPRINT TAB(15):"TERRAIN : ROLLING"
2470 LPRINT
2480 GOSUB 2700
2490 GOTO 2680
2500 REM  * USE OKUMURA MODEL FOR QUASI-SMooth TERRAIN  *
2510 LPRINT TAB(15):"TERRAIN : QUASI-SMooth"
2520 LPRINT
2530 REM  * SPECIFY AREA : URBAN / SUBURBAN / OPEN  *
2540 PRINT "SPECIFY AREA : ENTER 1,2,3 OR 4"
2550 PRINT "   1 FOR URBAN AREA : MEDIUM SMALL CITY"
2560 PRINT "   2 FOR URBAN AREA : LARGE CITY"
2570 PRINT "   3 FOR SUBURBAN AREA"
2580 PRINT "   4 FOR OPEN AREA"
2590 INPUT "AREA":AR
2600 ON AR GOTO 2610,2630,2650,2670
2610 GOSUB 2600
2620 GOTO 2680
2630 GOSUB 2930
2640 GOTO 2680
2650 GOSUB 3070
2660 GOTO 2680
2670 GOSUB 3220
2680 D = (INT(D#1000))/1000
2690 RETURN
2700 REM **************************************************************************
2710 REM  * COROUTINE NO.4.1 (RANGE CALCULATIONS USING EQLI MODEL)  *
2720 REM  ************************************************************************
2730 REM  * APPLY CORRECTION TO ANTENNA HEIGHTS  *
2740 LET HT = SQR((HT^2)+(HA^2))
2750 LET HR = SQR((HR^2)+(HA^2))
2760 LET D=11/40*(((20/LGC)*LOG(FC))+(20/LGC)*LOG(HT*HR))
2770 LET D=10^-D
NETWORK DESIGN

2780 LET LDH=BB+(40/LGC)*LOG(DH)+((20/LGC)*LOG(FC))-(20/LGC)*LOG(HT+HR)
2790 RETURN

2800 REM \n
2810 REM * CORDUTINE NO.4.2 (RANGE CALCULATIONS - OKUMURA MODEL) *
2820 REM * URBAN MEDIUM SMALL CITY *
2830 REM \n
2840 LPRTAB(15):"AREA : URBAN MEDIUM SMALL CITY"
2850 LPRT

2860 LET AHM=((1.1/LGC)*LOG(FC))-(((1.56/LGC)*LOG(FC))-8)
2870 LET A=69.55+((26.16/LGC)*LOG(FC))-(((13.82/LGC)*LOG(HT))-AHM)
2880 LET D=(L-A)/((44.9-(6.55/LGC)*LOG(HT)))
2890 LET D=10^D
2900 LET LDH=69.55+((26.16/LGC)*LOG(FC))-(((13.82/LGC)*LOG(HT))
2910 LET LDH=LDH-AHM+((44.9-(6.55/LGC)*LOG(HT)))*(1/LGC)*LOG(DH)
2920 RETURN

2930 REM \n
2940 REM * CORDUTINE NO.4.3 (RANGE CALCULATIONS - OKUMURA MODEL) *
2950 REM * URBAN LARGE CITY *
2960 REM \n
2970 LPRTAB(15):"AREA : URBAN LARGE CITY"
2980 LPRT

2990 IF FC<200 THEN LET AHM=((8.29/((1/LGC)*LOG(1.54*HR)))/2)-1.1
3000 IF FC<200 THEN LET AHM=((3.26/((1/LGC)*LOG(11.75*HR)))^2)-4.97
3010 LET A=69.55+((26.16/LGC)*LOG(FC))-(((13.82/LGC)*LOG(HT))-AHM)
3020 LET D=(L-A)/((44.9-(6.55/LGC)*LOG(HT)))
3030 LET D=10^D
3040 LET LDH=69.55+((26.16/LGC)*LOG(FC))-(((13.82/LGC)*LOG(HT))
3050 LET LDH=LDH-AHM+((44.9-(6.55/LGC)*LOG(HT)))*(1/LGC)*LOG(DH)
3060 RETURN

3070 REM \n
3080 REM * CORDUTINE NO.4.4 (RANGE CALCULATIONS - OKUMURA MODEL) *
3090 REM * SUBUERAN AREA *
3100 REM \n
3110 LPRTAB(15):"AREA : SUBURBAN AREA"
3120 LPRT

3130 LET AHM=((1.1/LGC)*LOG(FC))-7.7*HR-(((1.56/LGC)*LOG(FC))-8)
3140 LET A=69.55+((26.16/LGC)*LOG(FC))-(((13.82/LGC)*LOG(HT)))
3150 LET A=A-(2*((1/LGC)*LOG(FC/28)))^2^-5.4-AHM
3160 LET D=(L-A)/((44.9-(6.55/LGC)*LOG(HT)))
3170 LET D=10^D
3180 LET LDH=69.55+((26.16/LGC)*LOG(FC))-(((13.82/LGC)*LOG(HT))
3190 LET LDH=LDH-AHM+((44.9-(6.55/LGC)*LOG(HT)))*(1/LGC)*LOG(DH)
3200 LET LDH=LDH-2*((1/LGC)*LOG(FC/28)))^2^-5.4
3210 RETURN
NETWORK DESIGN

3220 REM
3230 REM ****************************:
3240 REM ****************************:
3250 REM ****************************:
3260 LPRINT TAB(15);"AREA = OPEN AREA"
3270 LPRINT
3280 LET AHM=((((1,1/LGC)*LOG(FC))-.7)*HR)-(((1,56/LGC)*LOG(FC))-8)
3290 LET A=69.55+((26,16/LGC)*LOG(FC))-(((13,82/LGC)*LOG(HT))-AHM)
3300 LET AHH=((-4.78*((1/LGC)*LOG(FC))))*2+((18.33/LGC)*LOG(FC))-60.94
3310 LET L=(L-A)*((1/(44,9-((6.55/LGC)*LOG(HT)))))
3320 LET D=10**L
3330 LET LDH=69,55+((26,16/LGC)*LOG(FC))-(((13,82/LGC)*LOG(HT)))
3340 LET LDH=LDH-AHH+((44.9-((6.55/LGC)*LOG(HT)))*((1/LGC)*LOG(DH))
3350 LET LDH=LDH-((4.78*(((1/LGC)*LOG(FC)))*2)+((18.33/LGC)*LOG(FC)))-40.94
3360 REM
3370 REM ****************************:
3380 REM ****************************:
3390 REM ****************************:
3400 LET LD1F = L - LDH
3410 PRINT
3420 INPUT "STEP FOR RANGE CORRECTION IN Kms.";DCHR
3430 LET D=DCHR
3440 REM ****************************:
3450 REM ****************************:
3460 IF TR=1 THEN 3490
3470 LET HT=SGR((HT^2)+(HA^2))
3480 LET HR=SGR((HR^2)+(HA^2))
3490 GOSUB 3410
3500 GOSUB 3470
3510 REM ****************************:
3520 LET D=D+DCHR
3530 GOSUB 3990
3540 IF LCR>LD1F THEN 3590
3550 IF LCR>LD1F THEN 3580
3560 LET LDIF=LD1F-LCR
3570 GOTO 3510
3580 LET D=D-DCHR
3590 D=(INT(D*1000))/1000
3600 REM
3610 REM ****************************:
3620 REM ****************************:
3630 REM ****************************:
3640 REM ****************************:
3650 LET AA=((2.08*10^-8)*DH)/(1000-3.75*DH)
3660 IF (HT*HR*FC)<AA THEN D1=(1.4*(T+HR*FC))/(.47*10^-5)
3670 IF (HT*HR*FC) > AA THEN D1 = 1.1*DH*(1.08*10^-8)*(HT*HR*FC)
3680 IF D1 < 98 THEN D1 = 0.99*DH
3690 IF FC > 160 THEN D2 = DH - (16.1/LGC) * (LOG(FC)) + 91.8
3700 IF FC < 160 THEN D2 = DH - (48.3/LGC) * (LOG(FC)) + 163
3710 PRINT; PRINT
3720 PRINT "HIGH MODEL PARAMETERS"
3730 PRINT
3740 PRINT "D1 = " ; D1:
3750 D2 = " ; D2
3760 PRINT
3770 REM
3780 REM * COROUTINE NO. 5.2 (PARAMETERS FOR LOW MODEL) *
3790 REM
3800 REM CALCULATE PARAMETERS REQUIRED FOR APPLYING CORRECTION
3810 LET DCF = 10^-((1/LGC) * (LOG(FC)) + (0.75/LGC) * LOG(HR*HR) - 0.92)
3820 IF FC > 100 THEN DC = 59.9/(FC^((1/3)))
3830 IF FC < 100 THEN DC = 125/(FC^((1/2)))
3840 IF FC > 160 THEN D2 = DH - (16.1/LGC) * (LOG(FC)) + 91.8
3850 IF FC > 160 THEN D2 = DH - (48.3/LGC) * (LOG(FC)) + 163
3860 IF SR = 1 THEN 3880
3870 GOTO 3910
3880 IF FC < 100 THEN M = (0.5/LGC) * LOG(FC) - 35
3890 IF FC > 100 THEN M = (FC^-((1/3)))/7
3900 GOTO 3920
3910 LET M = (FC^-((1/3)))/7
3920 IF M > 5 THEN M = 5
3930 PRINT
3940 PRINT "LOW MODEL PARAMETERS"
3950 PRINT
3960 PRINT "DCF = " ; DCF:
3970 D1 = " ; D1:
3980 PRINT
3990 REM
4000 REM * COROUTINE NO. 5.3 (ITERATIONS FOR RANGE CORRECTION) *
4010 REM
4020 REM CHECK APPLICABILITY OF MODEL
4030 REM
4040 REM SELECT APPROPRIATE MODEL
4050 IF DC > DCF THEN 4180
4060 IF D1 > 111 - (15/LGC) * LOG(HT*HR) + (40/LGC) * LOG(D) + 0.62*(M^2) - (10 - D)
4070 IF D1 > D2 THEN L1 = 111 - (15/LGC) * LOG(HT*HR) + (40/LGC) * LOG(D) + 0.62*(M^2) - (10 - D)
4080 IF D1 > D2 THEN L1 = 111 - (15/LGC) * LOG(HT*HR) + (40/LGC) * LOG(D) + 0.62*(M^2) - (10 - D)
4090 LET L2 = 58 + (20/LGC) * LOG(DC/D2)
4100 IF D>D1 THEN L2=L2+50*((D-D1)/(D2-D1))
4110 IF D>D2 THEN L2=L2+50*(20/LGC)*LOG(D/D2)
4120 REM CALLITERATION
4130 IF L1<L2 THEN 4180
4150 LET LCR=(40/LGC)*LOG(D/(D-DCR))
4160 IF D>DC THEN LCR=LCR+2+62.5*(D-DCR)
4170 GOTO 4210
4180 LET LCR=(20/LGC)*LOG(D/(D-DCR))
4190 IF D>D1 THEN LCR=LCR+50*(DCR/(D2-D1))
4200 IF D>D2 THEN LCR=(40/LGC)*LOG(D/(D-DCR))
4210 RETURN
4220 REM ###################################################################
4230 REM < SUBROUTINE NO. 6 (ALLOWABLE LOSS CD-CHANNEL) >
4240 REM ###################################################################
4250 REM < SPECIFY PROBABILITY OF INTERFERENCE >
4260 PRINT
4270 INPUT "PROBABILITY OF INTERFERENCE, PX(%) :";PX
4280 LPRINT TAB(20):"PROBABILITY OF INTERFERENCE, PX :";PX,"%
4290 LPRINT
4300 PRINT
4310 INPUT "TERRAIN FACTOR, TF(db) :";TF
4320 LPRINT TAB(20):"TERRAIN FACTOR, IF :";TF,"db"
4330 LPRINT
4340 PRINT
4350 INPUT "PROTECTION RATIO, PRC(db) :";PRC
4360 LPRINT TAB(20):"PROTECTION RATIO, PRC :";PRC,"db"
4370 LPRINT
4380 IF PX<50 THEN PFC=(-9.258+0.076*PX+(3.202/LGC)*LOG(PX))
4390 IF PX<50 THEN ENC=(-9.258+0.076*PX-(3.202/LGC)*LOG(100-PX))
4400 IF PX=50 THEN PFC=0
4410 LET PRC=PRC-PMS*PMC
4420 LET PR=PR-PMS*PMC-PRC
4430 PRINT
4440 PRINT "RECEIVED SIGNAL LEVEL, Pr :";Pr,"dbm"
4450 LET L=PT-LT+GT+GR-LR-PR-TF
4460 RETURN
4470 REM ###################################################################
4480 REM < SUBROUTINE NO. 7 (INTERFERENCE RADIUS CALCULATIONS) >
4490 REM ###################################################################
4500 REM CALCULATE PARAMETERS REQUIRED FOR CALCULATIONS
4510 REM CALL P2 APPLY CORRECTION TO ANTENNA HEIGHTS
4520 IF TR=1 THEN 4550
4530 LET HT=SQR((HT2)+(HA^2))
4540 LET HR = SQRT((HR^2)+(HA^2))
4550 REM HIGH MODEL
4560 GOSUB 3610
4570 LET D = D1
4580 IF L L=2 THEN 4580
4590 GOSUB 4930
4660 IF L L=1 THEN 4630
4670 LET D = D - 1
4680 D = (INT(D*1000))/1000
4690 PRINT "INTERFERENCE RADIUS USING HIGH MODEL: \( d_i = \text{"} D \text{"}" Kms.")
4700 PRINT
4710 LET DHIG=D
4720 REM LOW MODEL
4730 GOSUB 3770
4740 LET D = DCF
4750 LET D = D + 1
4760 GOSUB 4810
4770 IF D < DCF THEN 4800
4780 IF L > L1 THEN 4700
4790 IF L = L1 THEN 4760
4800 LET D = D - 1
4810 GOSUB 4930
4820 PRINT "INTERFERENCE RADIUS USING LOW MODEL: \( d_i = \text{"} E \text{"}" Kms.")
4830 PRINT
4900 LET DLOW=D
4910 RETURN
4920 REM *******************
4930 REM * COROUTINE NO. 7.1 (INTERFERENCE RADIUS CALCULATIONS) *
4940 REM * USING LOW MODEL *
4950 REM *******************
4960 IF D < DCF THEN 4710
4970 LET L1 = 11 - (15/LGC) * LOG(HT*HR) + (40/LGC) * LOG(D)
4980 IF D DCF THEN L1 = 11 - (15/LGC) * LOG(HT*HR) + (20/LGC) * LOG(D) * DC
+ .62 * M(D-DC)
4990 IF D >= D DCF THEN L1 = 11 - (15/LGC) * LOG(HT*HR) + (40/LGC) * LOG(D)
+ .62 * M(D2=DC)
5000 IF D < D2 THEN L1 = L1 + (20/LGC) * LOG(D2/D)
5010 GOTO 4930
5020 PRINT "MODEL NOT APPLICABLE"
5030 PRINT
5040 RETURN
5050 REM *******************
5060 REM * COROUTINE NO. 7.2 (INTERFERENCE RADIUS CALCULATIONS) *
5070 REM * USING HIGH MODEL *
5080 REM *******************
NETWORK DESIGN

4980 LET L2=38+(20/LGC)*LOG(FC*D)
4990 IF D>D1 THEN L2=L2+50*((D-L1)/(D2-D1))
5000 IF D<D2 THEN L2=38+(20/LGC)*LOG(FC*D)+50+(20/LGC)*LOG(D2/D)
5010 RETURN
5020 REM **********************************************************
5030 REM SUBROUTINE NO. 6 (ALLOWABLE LOSS ADJACENT CHANNEL)
5040 REM **********************************************************
5050 REM 7 SPECIFY LOCATION PROBABILITY *
5060 PRINT
5070 INPUT "LOCATION PROBABILITY, Px(%)";PX
5080 LPRINT TAB(20):"LOCATION PROBABILITY, Pz(%)";FX;"%"
5090 LPRINT
5100 PRINT
5110 INPUT "PROTECTION RATIO, PRA(dB)";PRA
5120 LPRINT TAB(20):"PROTECTION RATIO, PRA(dB)";PRA;"dB"
5130 LPRINT
5140 IF PX<50 THEN PMAI=(-9.258+.076*PX+1.302/LGC)*LOG(PX))
5150 IF PX>50 THEN PMAI=1.638+.076*PX-(2.202/LGC)*LOG(100-PX))
5160 IF PX=50 THEN PMAI=0
5170 LET PRA=PMAI-PMA
5180 LET PR=PR+PMA+PRA
5190 PRINT
5200 PRINT "RECEIVED SIGNAL LEVEL, Pr(%)";PR;"dBm"
5210 LET L=PT-LT+GT-QR-LR-PR
5220 RETURN
5230 REM **********************************************************
5240 REM SUBROUTINE NO. 9 (NETWORK PARAMETERS)
5250 REM **********************************************************
5260 LET MMIN=((R+RI)^2)/(3*K(R2))
5270 IF MMIN<12 THEN MMIN=R+RA
5280 LET MMAX=(SGR(3))*R
5290 LET DRMN=R+RI
5300 LET NOPT=((R+RI)^2)/(R+RA)^2)
5310 FOR N=1 TO 25 STEP 1
5320 IF N>NOPT THEN 5340
5330 NEXT N
5340 DMAX=MMAX*(SGR(N))
5350 IF MMIN<12 THEN MMIN=(R+RI)/(SGR(N))
5360 IF IMG3="" & IMG3=""&IMG3=""
5370 PRINT
5380 PRINT TAB(15):"NETWORK PARAMETERS"
5390 PRINT
5400 PRINT USING IMG3=""&IMG3=""&IMG3=""
5410 PRINT
NETWORK DESIGN

5420 PRINT USING IMG3#:"LATTICE MODULUS. Mmax =":MMAX:"Kms."
5430 PRINT
5440 PRINT USING IMG3#:"COORDINATION DISTANCE. Dmin =":DMIN:"Kms."
5450 PRINT
5460 PRINT USING IMG3#:"COORDINATION DISTANCE. Dmax =":DMAX:"Kms."
5470 PRINT
5480 PRINT USING IMG3#:"NUMBER OF CELLS. Nmin =":NMIN
5490 PRINT
5500 PRINT USING IMG3#:"NUMBER OF CELLS. Noot =":N
5510 PRINT
5520 RETURN
5530 REM ****************************
5540 REM + SUBROUTINE NO. 10 (PRINT NETWORK PARAMETERS) +
5550 REM ****************************
5560 LPRINT USING IMG3#:"LATTICE MODULUS. Mmin =":MMIN:"Kms."
5570 LPRINT
5580 LPRINT USING IMG3#:"LATTICE MODULUS. Mmax =":MMAX:"Kms."
5590 LPRINT
5600 LPRINT USING IMG3#:"COORDINATION DISTANCE. Dmin =":DMIN:"Kms."
5610 LPRINT
5620 LPRINT USING IMG3#:"COORDINATION DISTANCE. Dmax =":DMAX:"Kms."
5630 LPRINT
5640 LPRINT USING IMG3#:"NUMBER OF CELLS. Nmin =":NMIN
5650 LPRINT
5660 LPRINT USING IMG3#:"NUMBER OF CELLS. Noot =":N
5670 LPRINT
5680 RETURN
5.3.3 RESULTS

For a given set of system parameters the programme determines the values of cell variables, which are used for designing the network. The results achieved are described in the subsequent pages.

A range of values for number of cells (N), Lattice modulus (M) and co-ordination distance (D) are obtained. Normally for a regular Lattice, minimum value of N provides optimum spectrum occupancy. However, in actual design, the displacement of base stations cannot follow the regular Lattice model. In that case a measure of interval between \( M_{\text{min}} \) and \( M_{\text{max}} \) determines the Lattice distortion acceptable in the design.

For the design to satisfy coverage criterion the actual \( M_{\text{max}} \) spacing must be checked. Similarly the actual spread of D values in the co-channel sublattices has to be examined. The actual \( D_{\text{min}} \) should comply with co-channel compatibility criterion. No adjacent channels should be assigned to adjacent stations for \( N \geq 12 \). The design is then automatically compatible to the adjacent channel criterion. But this decreases the spectrum utilization. However, for \( N < 12 \) checking of adjacent channel compatibility criterion is obligatory.
NETWORK DESIGN

OPTIMUM AREA COVERAGE WITH LIMITED RADIO CHANNELS

1. SYSTEM PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>fc = 170.0 MHz</td>
</tr>
<tr>
<td>Transmitter Power</td>
<td>Pt = 44.0 dBm</td>
</tr>
<tr>
<td>Transmitter Antenna Gain</td>
<td>Gl = 3.0 dB</td>
</tr>
<tr>
<td>Transmitter Antenna Height</td>
<td>ht = 30.0 mt</td>
</tr>
<tr>
<td>Transmitter Losses</td>
<td>Lt = 10.0 dB</td>
</tr>
<tr>
<td>Receiver Combiner Gain</td>
<td>Prs = -113.0 dBm</td>
</tr>
<tr>
<td>Receiver Antenna Height</td>
<td>hr = 2.0 mt</td>
</tr>
<tr>
<td>Receiver Antenna Gain</td>
<td>Gr = 0.0 dB</td>
</tr>
<tr>
<td>Receiver Losses</td>
<td>Lr = 0.0 dB</td>
</tr>
<tr>
<td>System Margin</td>
<td>SM = 0.0 dB</td>
</tr>
</tbody>
</table>

2. RADIO HORIZON

SURFACE = AVERAGE LAND

RADIO HORIZON DISTANCE. dh = 27.565 Kms.

3. SERVICE RADIUS

PROBABILITY OF COMMUNICATION. Px = 90 %

TERRAIN = ROLLING

SERVICE RADIUS. R = 11.93 Kms.

SYSTEM PERFORMANCE MARGIN = 14.48106 dB
4. INTERFERENCE RADIi

4.1 CO-CHANNEL INTERFERENCE RADIUS

PROBABILITY OF INTERFERENCE, Pr : 10 %
TERRAIN FACTOR, TF : 12 dB
PROTECTION RATIO, Pr : 26 dB
INTERFERENCE RADIUS CO-CHANNEL, R1 = 53.205 Kms.

4.2 ADJACENT CHANNEL INTERFERENCE RADIUS

LOCATION PROBABILITY, Pr : 90 %
PROTECTION RATIO, Pr : 24 dB
INTERFERENCE RADIUS ADJACENT CHANNEL, Ra = 5.956 Kms.

5. NETWORK PARAMETERS

LATICE MODULUS, Mmin = 17.89 Kms.
LATICE MODULUS, Mmax = 20.66 Kms.
COORDINATION DISTANCE, Dmin = 65.14 Kms.
COORDINATION DISTANCE, Dmax = 77.32 Kms.
NUMBER OF CELLS, Nmin = 9.94
NUMBER OF CELLS, Nopt = 14.00