

## RECOMMENDATION ITU-R F.1760

**Methodology for the calculation of aggregate equivalent isotropically radiated power (a.e.i.r.p.) distribution from point-to-multipoint high-density applications in the fixed service operating in bands above 30 GHz identified for such use\***

(2006)

**Scope**

This Recommendation provides a methodology which may be used to derive the a.e.i.r.p. for transmitting point-to-multipoint (P-MP) and multipoint -to-multipoint (MP-MP) high-density applications in the fixed service (HDFS) stations in bands above 30 GHz which may be used by administrations wishing to assess the potential interference from P-MP HDFS stations to other services.

The ITU Radiocommunication Assembly,

*considering*

- a) that an estimate of the aggregate equivalent isotropically radiated power (a.e.i.r.p.) from a deployment of point-to-multipoint (P-MP) high-density applications in the fixed service (HDFS) stations may be required by administrations to assess the potential interference from P-MP HDFS stations to other victim services on a national and bilateral basis;
- b) that using automatic transmitter power control (ATPC) in P-MP transmitters would reduce the aggregated radiated power;
- c) that the determination of a.e.i.r.p. could be improved by considering the topology, demographic data and deployment model within the defined area,

*recognizing*

1 that No. 5.547 of the Radio Regulations (RR) identifies the bands 31.8-33.4 GHz, 37-40 GHz, 40.5-43.5 GHz, 51.4-52.6 GHz, 55.78-59 GHz and 64-66 GHz as being available for high-density applications in the fixed service (HDFS),

*noting*

- a) that Resolution 75 (WRC-2000) invites ITU-R to develop, as a matter of urgency, the technical basis for determining the coordination area for the receiving earth station in the space research service (deep space) with HDFS transmitting stations in the 31.8-32.3 GHz and 37-38 GHz bands;
- b) that Resolution 79 (WRC-2000) invites ITU-R to conduct studies on the coordination distance between radio astronomy stations operating in the 42.5-43.5 GHz band and HDFS systems,

*recommends*

1 that the methodology described in Annex 1 may be used to determine the a.e.i.r.p. distribution from transmitting P-MP HDFS stations operating in bands above 30 GHz.

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\* This Recommendation also applies to multipoint -to-multipoint (MP-MP) high-density applications in the fixed service (HDFS).

## Annex 1

### **Methodology for the calculation of aggregate equivalent isotropically radiated power (a.e.i.r.p.) distribution from P-MP high-density applications in the fixed service operating in bands above 30 GHz**

#### **1 Introduction**

Resolution 75 (WRC-2000) requests the development of the technical basis for determining the coordination area for coordination between receiving earth stations in the space research service (deep space) and transmitting stations of high-density applications in the fixed service (HDFS), in the 31.8-32.3 GHz and 37-38 GHz frequency bands. In addition, Resolution 79 (WRC-2000) invites ITU-R to conduct studies on the coordination distance between radio astronomy stations operating in the 42.5-43.5 GHz band and HDFS systems.

This Recommendation provides methodologies which may be used to derive the a.e.i.r.p. for transmitting P-MP HDFS stations which may be used by administrations wishing to assess the potential interference from P-MP HDFS stations to other victim services in their national and bilateral discussions. The methodologies in this recommendation may be used as a basis for further study by administrations wishing to answer the *resolves* under Resolutions 75 (WRC-2000) and 79 (WRC-2000).

WRC-2000 adopted the RR 5.547 that identified certain bands above 30 GHz to be available for high-density applications in the fixed service. System specific characteristics are not identified, but it is expected that large numbers of terminals would be deployed within specified areas associated with traditional fixed service systems. These high density fixed service (P-MP HDFS) systems may have hundreds of terminals within a cell, and may consist of thousands of cells. This could give rise to a significant aggregation of e.i.r.p., and new approaches must be considered to model such effects.

One such approach, presented in the methodology below, is to determine the distribution of aggregate equivalent isotropically radiated power (a.e.i.r.p.) from P-MP HDFS stations dispersed over a defined area called a building block (BB). The a.e.i.r.p. takes into account:

- variation in transmitter and receiver heights;
- variation in station location and hop length;
- variation in antenna azimuth and associated gain towards a point on the horizon;
- variation in transmit power control.

These parameters can be convolved using an interference equation and Monte Carlo simulation to produce a distribution of a.e.i.r.p. at a receiving test point located on the horizon. Using this method, each cell can be modelled as an a.e.i.r.p. distribution that represents potentially large numbers of transmitters within the area defined by the BB.

The methodology is defined in three stages:

Stage 1 definition of P-MP HDFS system parameters;

Stage 2 deployment model;

Stage 3 convolution of system parameters to obtain the a.e.i.r.p. distribution.

These stages are described in the sections below, and an example application is presented in Appendix 1.

### 1.1 Use of Monte Carlo simulation

In order to calculate the a.e.i.r.p. distributions it is necessary to take into account the variation in input parameters, such as station locations and antenna azimuths. This can be done using a statistical modelling approach, such as a Monte Carlo methodology.

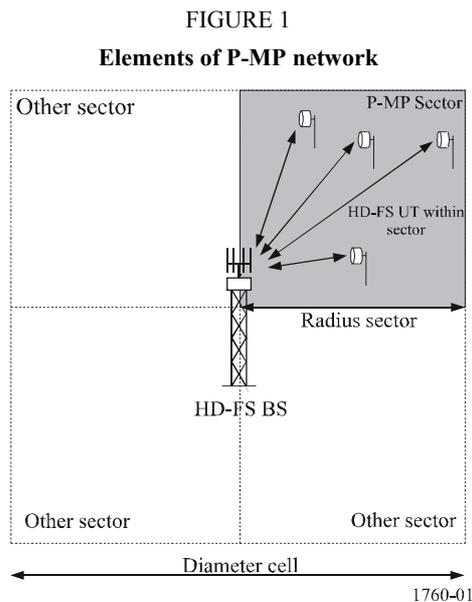
The Monte Carlo methodology is based on the principal of sampling random variables from their defined probability distributions. These distributions are defined in terms of maximum and minimum system parameters when defining the P-MP HDFS reference system (see § 3.2 below).

In order to get statistically meaningful results, a suitable number of samples are required when using the Monte Carlo approach. To determine the a.e.i.r.p. distributions, at least 10 000 samples should be taken.

### 1.2 Types of P-MP HDFS network

A number of architectures could be used to provide P-MP HDFS services. Two such are point-to-multipoint (P-MP) and multipoint-to-multipoint (MP-MP).

Figure 1 shows the elements of a P-MP system.



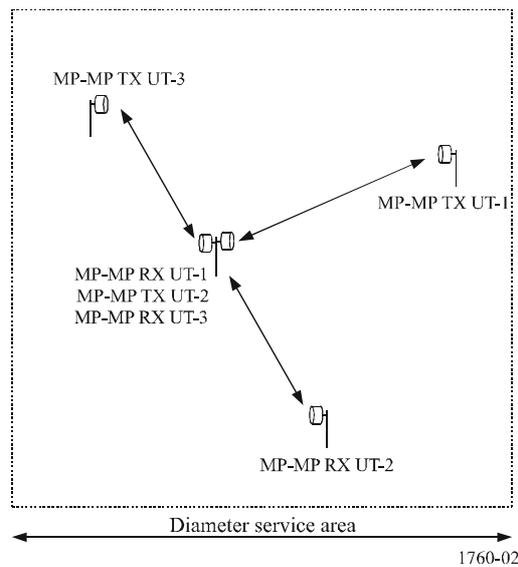
The architecture comprises:

- an area defined as the cell over which service is provided;
- at a location within this cell, typically the centre, is located the base station (BS);
- the cell is divided into a set of sectors, with service provided for each by a separate antenna;
- within each sector are located user terminals (UT)s;
- each UT has an antenna that points at the BS.

Note that a cell can consist of a single sector.

Figure 2 shows the elements of a MP-MP system.

FIGURE 2  
Elements of MP-MP network



The architecture comprises:

- an area over which service is provided;
- each node or user terminal (UT) is connected to at least one other;
- additional UTs can be connected to existing nodes.

## 2 Description of a.e.i.r.p. distribution methodology

### 2.1 Stage 1 – P-MP HDFS system parameters

The first stage is to define the P-MP HDFS system parameters. This can be done using the template Table 1.

TABLE 1  
P-MP HDFS model parameters

Parameter	Value	Units	Comment
Architecture	User specified	–	Either P-MP or MP-MP
Transmitter	User specified	–	Specify whether BS, UT or MP-MP
Tx antenna radiation pattern	User specified	–	
Tx peak antenna gain	User specified	dBi	
Tx height (above terrain):			
Min height	User specified	m	For P-MP systems, specify max height only. For MP-MP systems, antenna height selected at random between min and max value
Max height	User specified	m	
Number of cells	User specified	–	No. cells modelled for P-MP systems within BB size
Number of sectors per cell	User specified	–	Default is 1 for MP-MP systems

TABLE 1 (*end*)

Parameter	Value	Units	Comment
Number of users/sector or number of transmitting nodes	User specified	–	Specify number of simultaneously transmitting users, or MP-MP nodes
User location within sector	Random	–	Selected at random
Link path length: Min length Max length	User specified User specified	km km	Path length selected at random between min and max value. For P-MP systems the UT position is random within the sector.
Frequency	43	GHz	Default value
Reference bandwidth $B$	1	MHz	Default value
ATPC used	Yes/No	–	
Max Tx power Min Tx power	User specified User specified	dB(W/B MHz) dB(W/B MHz)	If ATPC not used, Tx power varied at random between min and max value within the reference bandwidth $B$ MHz
Nominal Rx input level	User specified	dB(W/B MHz)	If ATPC is used, set Tx power to achieve nominal Rx input level within the reference bandwidth $B$ MHz
Other losses	User specified	dB	Feeder and cable losses etc
Receiver	User specified	–	Specify whether BS, UT or MP-MP
Rx antenna radiation pattern	User specified	–	
Rx peak antenna gain	User specified	dBi	
Rx height (above terrain): Min height Max height	User specified User specified	m m	For P-MP systems, specify max height only. For MP-MP systems, antenna height selected at random between min and max value

## 2.2 Stage 2 – Deployment model

The second stage is to define the BB or reference area over which the P-MP HDFS stations will be deployed, and the location of the test points used to determine the a.e.i.r.p. on horizon.

The BB or reference area is defined as a constant area such as a rectangle of size 4 km × 4 km. Other reference areas can be considered, but the value selected must be consistent with how the a.e.i.r.p. is used. Within the BB area will be located a specified number of P-MP cells or MP-MP nodes.

The number of P-MP cells will depend upon cell size. So a BB of size 4 km × 4 km could contain one large cell or four smaller cells.

The horizon test points are located every  $x^\circ$  around a circle (where  $x < \text{the } 3 \text{ dB aperture of the FS antenna}$ ) which lies on the horizon as viewed from the centre of the reference area. The distance to horizon is given by:

$$D = \sqrt{2R_e h} \quad (1)$$

where:

- $D$  : distance to horizon
  - $R_e$  : equivalent radius of the Earth
  - $h$  : height of P-MP HDFS transmitting station.
- ( $D$ ,  $R_e$  and  $R$  are in the same units).

### 2.3 Stage 3 – Calculation of a.e.i.r.p. distribution

The Monte Carlo methodology consists of calculating the a.e.i.r.p. on the horizon from a deployment of P-MP HDFS stations for a series of samples. Each sample involves the convolution of varying inputs, such as station location, antenna azimuth and antenna height.

The value of a.e.i.r.p. is then given by the following formula:

$$AEIRP_i = 10 \cdot \log_{10} \sum_j^{N_{ut}} 10^{[P_j(d_{i,j}) + G_{tx,i,j} - L_p]/10} \quad (2)$$

where:

- $i$  : the sample number
- $j$  : the transmitter number
- $N_{ut}$  : overall number of active user terminals at a given time in a given BB (in case of P-MP system this takes into account the overall number of P-MP cells)
- $AEIRP_i$  : the aggregate e.i.r.p. for the  $i$ -th sample number (dBW)
- $P_j(d_{i,j})$  : transmit power for  $j$ -th transmitter to close link for random distance selected for  $j$ -th transmitter and  $i$ -th sample (dBW)
- $G_{tx,j}$  : transmit gain towards test point on horizon from  $j$ -th transmitter for  $i$ -th sample (dBi)
- $L_p$  : propagation loss: (dB)

Note that the summation is in linear units and other terms are in dB.

Each sample represents one configuration or deployment of P-MP HDFS stations within the BB, and the test point represents one random orientation of this BB.

Based upon equation (2), the a.e.i.r.p. distribution can be determined from the steps in the following sections, for P-MP or MP-MP architectures.

Propagation loss should be calculated using the appropriate path loss model<sup>1</sup>.

#### 2.3.1 P-MP algorithm

- Step 1: Set sample count  $N = 0$ .
- Step 2: Set each entry in array  $AEIRP$  of bins to zero.
- Step 3: For each BS repeat Steps 4 to 5.
- Step 4: Set the BS to be at the centre of the cell.

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<sup>1</sup> Choice of model could include free space path loss, Recommendation ITU-R P.452 with no clutter loss, or Recommendation ITU-R P.452 implementing clutter loss. Model used should be agreed between all parties noting that ignoring clutter loss may over estimate the actual a.e.i.r.p.

- Step 5: Set the BS height as specified.
- Step 6: While sample count  $N < N_{max}$  repeat Steps 7 to 23.
- Step 7: Select test point for this sample,  $TP_i$ , at random from those on the horizon.
- Step 8: Set  $AEIRP_{(W)}$  for this sample  $AEIRP_{i(W)} = 0$ .
- Step 9: For each BS repeat Steps 10 to 21.
- Step 10: For each sector for this BS repeat Steps 11 to 21.
- Step 11: For each UT within sector repeat Steps 12 to 21.
- Step 12: Set the UT position to be random within the area of its sector.
- Step 13: Set the UT antenna height to be at random between min height and max height.
- Step 14: Set the UT antenna to point at the relevant BS.
- Step 15: If power control is not used, then set the transmit power at a random value between max TX power and min TX power, and continue at Step 19.
- Step 16: Calculate the transmit power required to meet the required nominal receive input level using:

$$P_{TX} = R - (G_{TXb} - L_p - L_o + G_{RX}).$$

- Step 17: If  $P_{TX} > \text{Max TX power}$  then set  $P_{TX} = \text{Max TX power}$ .
- Step 18: If  $P_{TX} < \text{Min TX power}$  then set  $P_{TX} = \text{Min TX power}$ .
- Step 19: Calculate e.i.r.p. from this transmitter in direction of  $TP_i$  using:

$$EIRP_{i,j} = P_{TX} + G_{TXo} - L_p.$$

- Step 20: Increment  $AEIRP_{(W)}$  for this sample with this e.i.r.p.:

$$AEIRP_{i(W)} \Rightarrow AEIRP_{i(W)} + 10^{EIRP_{i,j}/10}.$$

- Step 21: When all transmitters have been included, convert  $AEIRP_{(W)}$  into dBW:

$$AEIRP_{i(dBW)} = 10 \log_{10}(AEIRP_{i(W)}).$$

- Step 22: Increment relevant bin in  $AEIRP$  array using  $AEIRP_{i(dBW)}$ .
- Step 23: When  $N_{max}$  steps have been completed, output  $AEIRP$  array as histogram and/or CDF.

**Key to equations:**

- $i$ : sample number
- $j$ : transmitter number
- $B$ : reference bandwidth (MHz)
- $P_{TX}$ : power at input to transmitter antenna (dB(W/B MHz))
- $R$ : nominal receive input level (dB(W/B MHz))
- $G_{TXb}$ : boresight transmit gain (dBi)
- $G_{TXo}$ : off-boresight transmit gain component (dBi)

- $L_p$ : propagation loss (dB) using the appropriate path loss model  
 $L_o$ : other losses (dB)  
 $G_{RX}$ : receive peak gain (dBi)  
 $EIRP$ : equivalent isotropically radiated power from single transmitter (dBW)  
 $AEIRP_{(W)}$ : aggregate e.i.r.p., from multiple transmitters (W)  
 $AEIRP_{(dBW)}$ : aggregate e.i.r.p., from multiple transmitters (dBW)  
 $AEIRP$ : array of bins which is used store  $AEIRP_{(dBW)}$  values that define an output histogram and/or CDF.

### 2.3.2 MP-MP algorithm

- Step 1: Set sample count  $N = 0$ .  
 Step 2: Set each entry in array  $AEIRP$  of bins to zero.  
 Step 3: While sample count  $N < N_{max}$  repeat Steps 4 to 23.  
 Step 4: Select test point for this sample,  $TP_i$ , at random from those on the horizon.  
 Step 5: Set  $AEIRP_{(W)}$  for this sample  $AEIRP_{i(W)} = 0$ .  
 Step 6: For each transmit node within test area repeat Steps 7 to 21.  
 Step 7: Set the TX station position to be random within the test area.  
 Step 8: Set the TX antenna height to be at random between min height and max height.  
 Step 9: Set the hop length to be random between minimum and maximum.  
 Step 10: Set the azimuth to be random between  $-180^\circ$  and  $+180^\circ$ .  
 Step 11: Calculate the position of the RX antenna.  
 Step 12: Set the RX antenna height to be at random between min height and max height.  
 Step 13: Set the RX antenna to point at the TX antenna.  
 Step 14: Set the TX antenna to point at the RX antenna.  
 Step 15: If power control is not used, then set the transmit power at a random value between max TX power and min TX power, and continue at Step 19.  
 Step 16: Calculate the transmit power required to meet the required nominal receive input level using:

$$P_{TX} = R - (G_{TXb} - L_p - L_o + G_{RX}).$$

- Step 17: If  $P_{TX} > \text{Max TX power}$  then set  $P_{TX} = \text{Max TX power}$ .  
 Step 18: If  $P_{TX} < \text{Min TX power}$  then set  $P_{TX} = \text{Min TX power}$ .  
 Step 19: Calculate e.i.r.p. from this transmitter in direction of  $TP_i$  using:

$$EIRP_{i,j} = P_{TX} + G_{TXo} - L_p.$$

- Step 20: Increment AEIRP for this sample with this e.i.r.p.:

$$AEIRP_{i(W)} \Rightarrow AEIRP_{i(W)} + 10^{EIRP_{i,j}/10}.$$

Step 21: When all transmitters have been included, convert  $AEIRP_{(W)}$  into dBW:

$$AEIRP_{i(dBW)} = 10 \log_{10}(AEIRP_{i(W)}).$$

Step 22: Increment relevant bin in  $AEIRP$  array using  $AEIRP_{i(dBW)}$

Step 23: When  $N_{max}$  steps have been completed, output  $AEIRP$  array as histogram and/or CDF.

**Key to equations:**

As above for P-MP.

**2.3.3 Adjustments to model**

The objective is to determine the a.e.i.r.p. in terms of dBW within a reference bandwidth such as 1 MHz. This could also be the mean a.e.i.r.p. for this reference bandwidth integrating over a larger, victim receiver bandwidth (e.g. 1 GHz). The calculations above therefore could require adjustment to scale to the required value.

The reference area may contain multiple P-MP HDFS cells, depending on cell type and environment. For P-MP deployment it will be necessary to determine:

- the number of active sectors that operate co-frequency;
- the number of user terminals per sector;
- hence, determine the number of active users per sector that operate co-frequency.

An adjustment must be made to take account of the total power from all P-MP HDFS channels that can be accommodated within the bandwidth of the receiving earth station, scaled to the reference bandwidth of 1 MHz.

$$Adj = 10 \log_{10}(N_{channels}) \tag{3}$$

where:

$$N_{channels} = \frac{ES_{RxBw}}{HDFS_{ULBw} + HDFS_{DLBw}}$$

where:

- $Adj$ : required adjustment
- $N_{channels}$ : number of channels that can be accommodated with the bandwidth of the receiving earth station
- $ES_{RxBw}$ : bandwidth of receiving earth station
- $HDFS_{ULBw}$ : bandwidth of P-MP HDFS station in uplink direction
- $HDFS_{DLBw}$ : bandwidth of P-MP HDFS station in downlink direction.

**2.3.4 Output from the methodology**

The output from the methodology will be a histogram and/or cumulative distribution function (CDF) of the a.e.i.r.p. distribution.

## Appendix 1 to Annex 1

### Example application of the a.e.i.r.p. distribution methodology

#### 1 Introduction

This Appendix presents an example application of the a.e.i.r.p. distribution methodology described in Annex 1 using parameters of a European FS system, assuming no clutter loss and free space propagation.

#### 2 Example application to urban commercial symmetric deployment

The methodology has been applied to a P-MP system deployed in an urban commercial environment operating with symmetric transmission bandwidths between the BS and UT. The a.e.i.r.p. distribution has been obtained for the uplink direction, i.e. UT to BS.

##### 2.1 System parameters

Using the P-MP HDFS system template, the parameters of the UCS system are shown in Table 1.

TABLE 1  
P-MP UCS parameters

Parameter	Value	Units
Architecture	P-MP	–
Transmitter	UT	–
Tx antenna radiation pattern	Bessel	–
Tx peak antenna gain	33.1	dBi
Tx height (above terrain):		
Min height	N/A	M
Max height	5	m
Number of cells	4	
Number of sectors per cell	4	–
Number of users/sector or number of transmitting nodes	136	–
User location within sector	Random	–
Link path length:		
Min length	N/A	km
Max length	1.4 km	km
Frequency	43	GHz
Reference bandwidth	1	MHz

TABLE 1 (end)

Parameter	Value	Units
ATPC used	Yes	–
Max Tx power	–30	dB(W/MHz)
Min Tx power	–70	dB(W/MHz)
Nominal Rx input level	–124.1	dB(W/MHz)
Other losses	1	dB
Receiver	P-MP BS	–
Rx antenna radiation pattern	EN 301 215-C2	–
Rx peak antenna gain	15	dBi
Rx height (above terrain):		
Min height	N/A	m
Max height	20	m

**2.2 Deployment model**

The UCS stations are deployed within the reference area, which is defined as a constant area of size 4 km × 4 km. From the parameters defined in Table 1, four cells are modelled (i.e. four base stations) each with four sectors per cell. There are 136 users per sector.

Figure 1 shows the UCS deployment model while Fig. 2 shows the location of the horizon test points calculated using equation (1) of § 2.2 of Annex 1.

FIGURE 1

**Example UCS distribution**

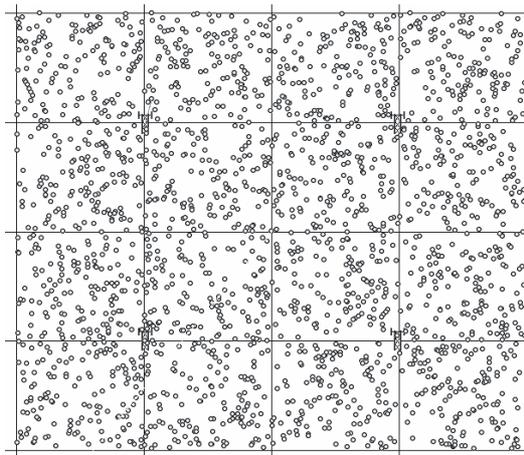
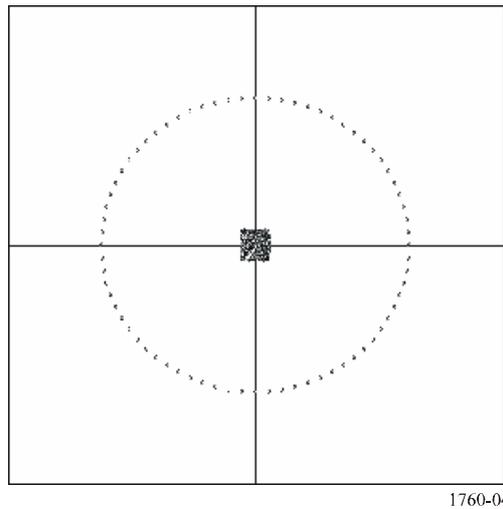


FIGURE 2  
Location of horizon test points



**2.3 Calculation of a.e.i.r.p. distribution**

The following adjustments are made to the algorithm specified in Annex 1 to take into account the number of channels that can be allocated within the bandwidth of the receiving earth station.

- Receiving earth station bandwidth: 1 000 MHz
- P-MP HDF5 UL bandwidth: 28 MHz
- P-MP HDF5 DL bandwidth: 28 MHz
- $N_{channels}$ : 17
- From equation (3):
- $Adj = 10 \log_{10}(17)$ : 12.3 dB

**2.4 Output from the methodology**

The a.e.i.r.p. histogram and cumulative distribution function for the UCS UT deployment are shown in the Fig. 3.

FIGURE 3  
Histogram and CDF distributions for the UCS user terminals

