POINT-TO-MULTIPOINT WIRELESS PLANNING SYSTEMS
Advanced Technology in Radio Communications

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POINT-TO-MULTIPOINT WIRELESS SYSTEMS

2.1. P-T-MP planning system
2.2. P-T-MP components
2.3. Manufacturers and distributors.
2.4. Market perspectives.
2.5. Trials.
2.6. Future trends.

OBJECTIVES

- **To study the different things that affect to the cells size calculation in a P-T-MP system → millimetric bands**
- **To show the steps in a P-T-MP system design**
- **To report about products and manufacturers and to emphasize about the key parameters of the different subsystems**
- **To give a global vision about market trends, such as the forecasts of P-T-MP system developments**

P-T-MP PLANNING SYSTEM

1. INTRODUCTION.

2. DEGRADATION MECHANISMS

3. THEORETICAL CELLULAR PLANNING
- **3.1. Channeling.**
- **3.2. Cell shapes.**
- **3.3. Frequency plans.**
- **3.4. Cell sizes.**

4. STATISTIC MODELING.
- **4.1. Channel modeling.**
- **4.2. Hypothesis.**

2.1. P-T-MP PLANNING SYSTEM *(1):*

INTRODUCTION

1. INTRODUCTION

Probably the hardest part in a wireless network deployment is the planification

In P-T-MP systems, the location choice and the correct size of cells is a critical point to make sure the network is going to satisfy QoS ratios and operator costs.

So, a vital question is the calculation of the *cell size*

2.1. P-T-MP PLANNING SYSTEM *(2):*

DEGRADATION MECHANISM (1)

2. DEGRADATION MECHANISMS

There are different mechanisms to calculate the balance of powers in a radio link

- **Attenuation by free-space propagation.**
- **Atmospheric attenuation (gases, clouds and fog).**
- **Attenuation and Scattering in rain and others hydrometeors.**
- **Attenuation by vegetation.**
- **Attenuation caused by buildings: diffraction.**

We pretend to characterize the model in the millimetric band

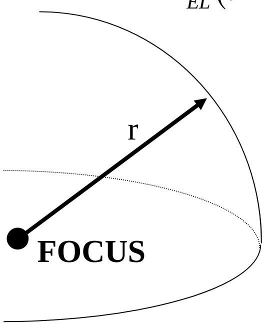
2.1. **P-T-MP PLANNING SYSTEM *(3):***

DEGRADATION MECHANISM (2)

FREE-SPACE PROPAGATION

Spherical wave modelling

$$A_{EL}(dB) = 20 \cdot \log\left(\frac{4\pi d}{\lambda}\right) = 92{,}4 + 20 \cdot \log(d \cdot f)$$



d = distance in km.
f = frequency in GHz

f= 3,5 GHz, d= 6,7 km
f= 26 GHz , d= 0,92 km ⇨ **A_{FS}= 120 dB**

2.1. **P-T-MP PLANNING SYSTEM *(4):***

DEGRADATION MECHANISM(3)

ATMOSPHERIC ATTENUATION (1): GASES AND RAIN

ITU-R P.676-3 recommendation. Is a semi-empirical model to evaluate the specific attenuation because of dry wind and water vapor for any pressure, temperature and humidity value.

Rough formulaes

$$\gamma_0 = \left(\frac{7{,}27 r_t}{f^2 + 0{,}351 r_p^2 r_t} + \frac{7{,}5}{(f-57)^2 + 2{,}4 r_p^2 r_t^5} \right) f^2 r_p^2 r_t \times 10^{-3}$$

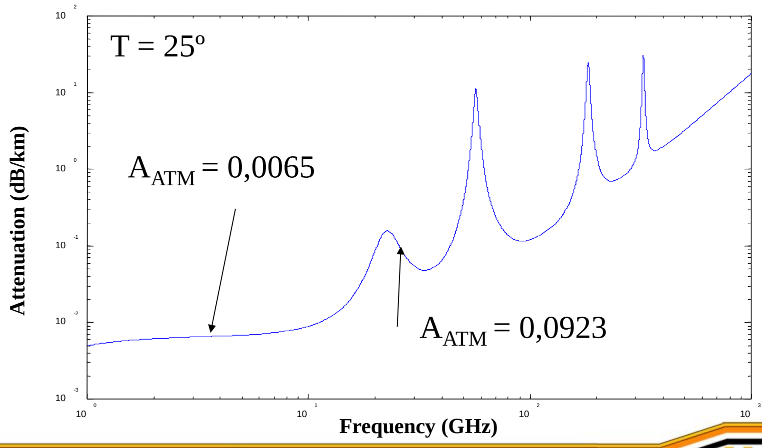
f = frequency (GHz)
r_p=p/1013, p=pressure (hPa)
r_t=288/(T+273), T= Temperature (ºC)
Valid for f<57 GHz with miscalculation < 0,1 dB/km (15%)

2.1. P-T-MP PLANNING SYSTEM (5):

DEGRADATION MECHANISM (4)

ATMOSPHERIC ATTENUATION (2): GASES AND RAIN

$$A_{ATM} = \gamma_O + \gamma_W$$



2.1. P-T-MP PLANNING SYSTEM (6):

DEGRADATION MECHANISM (5)

ATMOSPHERIC ATTENUATION (3): CLOUDS AND FOG

ITU-R P.840-2 RECOMMENDATION

Composition: tiny raindrops, generally r < 0,01 cm

→ **Rayleigh approximation (f < 200 GHz)**

$$A_N(dB/km) = K_L M$$

K_L: specific attenuation coefficient (dB/km)/(g/m^3)
M: liquid water density in clouds or fog (g/ m^3)
M=0,05 g/ m^3 in moderate fog (visibility 100 m)
M=0,5 g/ m^3 in thick fog (visibility 50 m)

This type of attenuation begins to be notable under 100 GHz

2.1. **P-T-MP PLANNING SYSTEM** *(7):*

DEGRADATION MECHANISM (6)

ATTENUATION AND SCATTERING IN RAIN AND ANOTHER HIDRO-METEORS (1)

There are a huge kind of models to predict attenuation caused by hidro-meteors. Mathematic formulae is sort of difficult and takes into account several things, such as raindrops, snowballs or ice particles.

- **Dielectric characteristics (Deybe model).**
- **Shape, speed and behavior over the fallen .**
- **Raindrop size distribution (RSD)**

2.1. **P-T-MP PLANNING SYSTEM** *(8):*

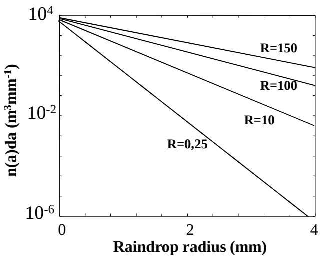
DEGRADATION MECHANISM (7)

ATTENUATION AND SCATTERING IN RAIN AND ANOTHER HIDRO-METEORS (2)

RSD (raindrop size distribution) **defines the number of raindrops that fall in a unit volume with a radius between a-da/2, a+da/2**

$$n(a)da = N_0 e^{-\Delta a} da \quad \text{(Marshall-Palmer)}$$

N_0=1.6x104 ($m^3 mm^{-1}$)
Δ=8,2$R^{-0.21}$ (mm-1)
a: radius in mm
R: rain intensity (mm/h)



Subsequently Gamma, Weibull, Joss models ...

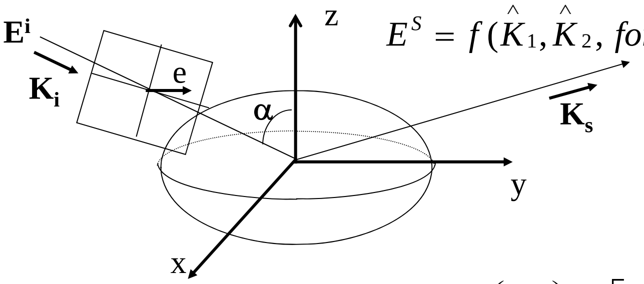
2.1. **P-T-MP PLANNING SYSTEM** *(9):*

DEGRADATION MECHANISM (8)

ATTENUATION AND SCATTERING IN RAIN AND ANOTHER HIDRO-METEORS (3)

Scattering properties

$$E^S = f(\hat{K}_1, \hat{K}_2, forma)r^{-1}e^{-jkr}$$



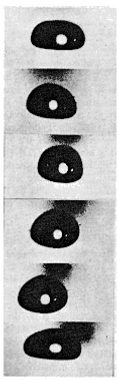
Crossed sections $Q_t = Q_a + Q_s = -\left(\frac{4\pi}{k}\right)\mathrm{Im}\left[\hat{e}\cdot f\left(\hat{K}_1, \hat{K}_2\right)\right]$

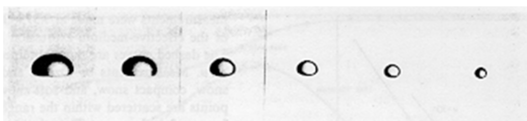
Absorbed power **Diffused power**

2.1. **P-T-MP PLANNING SYSTEM** *(10):*

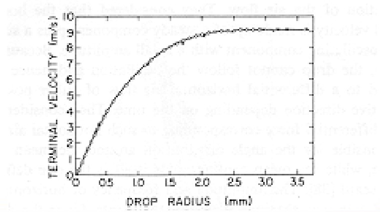
DEGRADATION MECHANISM (9)

ATTENUATION AND SCATTERING IN RAIN AND ANOTHER HIDRO-METEORS (3b)





Photographies of raindrops with different sizes. From left to right the radius are (mm): 4.00, 3.675, 2.90, 2.85, 1.725, 1.35.



2.1. P-T-MP PLANNING SYSTEM (11):

DEGRADATION MECHANISM (10)

ATTENUATION AND SCATTERING IN RAIN AND ANOTHER HIDRO-METEORS (4)

Attenuattion calculus

It must be established a relationship between easily measurable data and rain attenuation

$$A_{LL}\left(dB/km\right) = 4.343 \times \int Q_t\left(a\right)\underbrace{n\left(a\right)da}$$

RSD: depends on R

ITU-R P.838 model

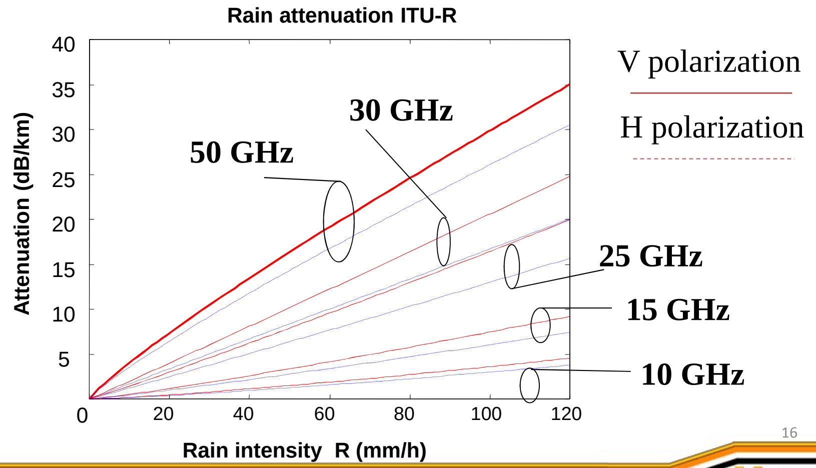
$$A_{LL}\left(dB/km\right) = kR^{\alpha}$$

K, α: constants tabulated according to the area

2.1. P-T-MP PLANNING SYSTEM (12):

DEGRADATION MECHANISM (11)

ATTENUATION AND SCATTERING IN RAIN AND ANOTHER HIDRO-METEORS (5)



2.1. **P-T-MP PLANNING SYSTEM** *(13):*

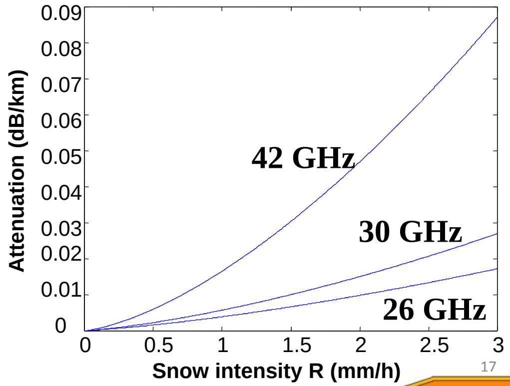
DEGRADATION MECHANISM (12)

ATTENUATION AND SCATTERING IN RAIN AND ANOTHER HIDRO-METEORS (6)

With regards to snow, introduced attenuation is few important and parameters variability in snowballs in less than in raindrops.

$$A_{NIEVE} = 0{,}00349\frac{R^{1,6}}{\lambda^4} + 0{,}00224\frac{R}{\lambda}$$

(dB/km)



2.1. **P-T-MP PLANNING SYSTEM** *(14):*

DEGRADATION MECHANISM (13)

ATTENUATION AND SCATTERING IN RAIN AND ANOTHER HIDRO-METEORS (7)

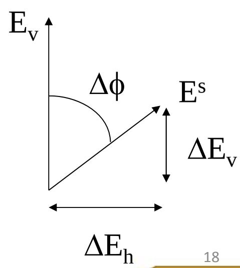
Depolarization

If we consider the real situation of no spheric drops, the effect of rain over incident field of vertical and horizontal components , they can produce depolarization

$$\Delta\, A_{h,v} = 8{,}686 \cdot \mathrm{Im}\left(k_{h,v}\right)L$$ **Amplitude**

$$\Delta\, \phi_{h,v} = \left(\frac{180}{\pi}\right) \cdot \mathrm{Re}\left(k_{h,v}\right)L$$ **Phase**

$$k_{h,v} = \left(\frac{2\pi}{k}\right)\int f_{h,v}n(a)da$$ **Propagation constant**



2.1.* P-T-MP PLANNING SYSTEM *(15):

DEGRADATION MECHANISM (14)

ATTENUATION AND SCATTERING IN RAIN AND ANOTHER HIDRO-METEORS (8)

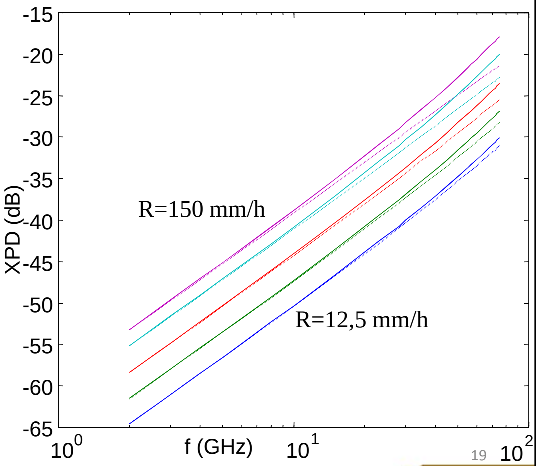
Depolarization

$$XPD_h = 20 \cdot \log\left(\frac{\Delta E_v}{E_h}\right)$$

$$XPI_h = 20 \cdot \log\left(\frac{\Delta E_h}{E_h}\right)$$

$$XPD_v = 20 \cdot \log\left(\frac{\Delta E_h}{E_v}\right)$$

$$XPI_v = 20 \cdot \log\left(\frac{\Delta E_v}{E_v}\right)$$

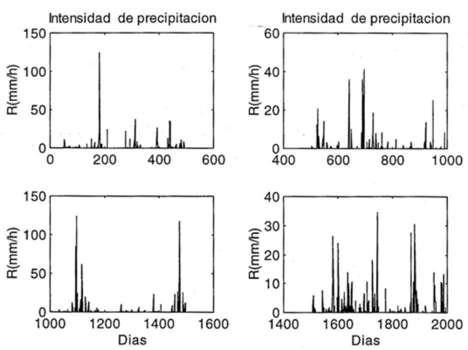


2.1.* P-T-MP PLANNING SYSTEM *(16):

DEGRADATION MECHANISM (15)

EXAMPLE OF ATTENUATION CALCULUS CAUSED BY RAIN: VALENCIA METROPOLITAN AREA

The Institute Meteorological of Valencia (IMV) provides the maximum rain fall intensities in a day.



$$\overline{R} = 1{,}222$$

$$\max(R) = 124.8$$

$$\min(R) = 0{,}2$$

$$\sigma = 6.519$$

$$\sigma^2 = 42{,}5$$

2.1. **P-T-MP PLANNING SYSTEM** ***(17):***

DEGRADATION MECHANISM (16)

EXAMPLE OF ATTENUATION CALCULUS CAUSED BY RAIN: VALENCIA METROPOLITAN AREA

In order to calculate statistics for a long term we use the ITU-R P.530-7 model recommendation. We obtain an expression for the exceeded attenuation calculus in function of 'p' time.

$$\frac{A_p}{A_{0,01}} = 0{,}12\,p^{-(0{,}546+0{,}043\log p)} \qquad A_{0,01} = f(R_{0,01})$$

If we use the ITU-R tabulated value, in Levante area, $R_{0,01}$= 42 mm/h

Much better than observed value

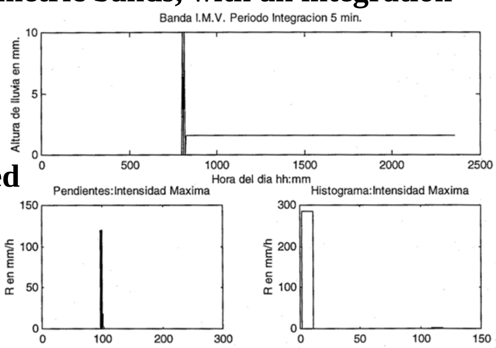
2.1. **P-T-MP PLANNING SYSTEM** ***(18):***

DEGRADATION MECHANISM (17)

EXAMPLE OF ATTENUATION CALCULUS CAUSED BY RAIN: VALENCIA METROPOLITAN AREA

Calculus of $R_{0,01}$ in function of the IMV data
It can not be made in order to maximum intensities, so we need to use the pluviometric bands, with an integration time of 10 minutes.

In order to obtain precise results, we need less integration times, so we use a process.

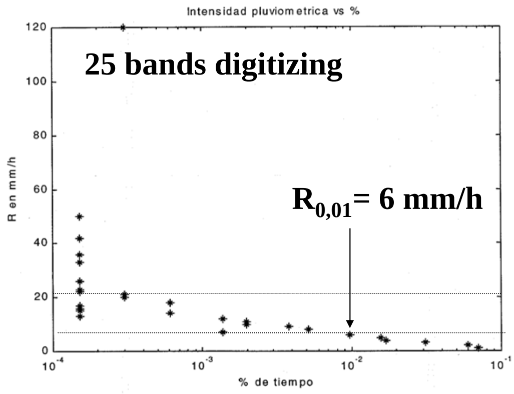


2.1. **P-T-MP PLANNING SYSTEM *(19):***

DEGRADATION MECHANISM (18)

EXAMPLE OF ATTENUATION CALCULUS CAUSED BY RAIN: VALENCIA METROPOLITAN AREA

Calculus of $R_{0,01}$ in function of IMV data



ITU-R isopleth

Pessimist planning

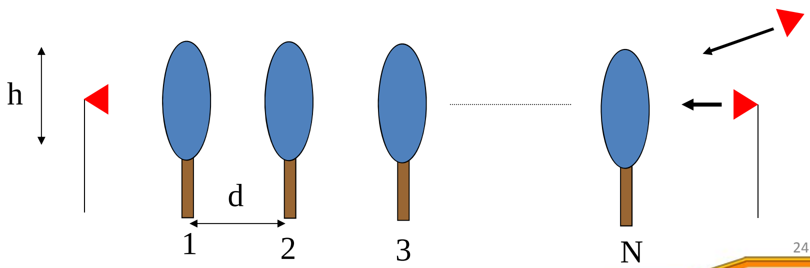
2.1. **P-T-MP PLANNING SYSTEM *(20):***

DEGRADATION MECHANISM (19)

ATTENUATION BY VEGETATION (1)

They exist many empiric models of attenuation for a plane wave that travels through vegetation in function of the frequency.

This models depend on the type of the tree as well as the type of the trunk, the thickness of the trunk and the amount of leafs and branchs.



2.1. **P-T-MP PLANNING SYSTEM** *(21):*

DEGRADATION MECHANISM (20)

ATTENUATION BY VEGETATION (2)

Models

1. **exponential ITU-R. law**

$$A_{VEG} = Bf^{0,3}d^{C}$$

f: frequency (MHz)
d: vegetation depth (m)
B, C: tabulated constants.

This model is quite wrong if we compare with experimental measurements. In measurements we can see that exist a penetration depth from which the attenuation do not increase the value, because the propagation mechanism is the scattering.

2.1. **P-T-MP PLANNING SYSTEM** *(22):*

DEGRADATION MECHANISM (21)

ATTENUATION BY VEGETATION (3)

2. MAR (Maximum Attenuation Rate)

$$A_{VEG} = A_m\left(1 - e^{-\frac{R\times d}{A_m}}\right)$$

A_m: Maximum attenuation
d: depth vegetation (m)
R: initial gradient of the ATT curve.

A_m and R can be obtained from the measurements through regression

3. NZG (Non Zero Gradient). MAR improved.

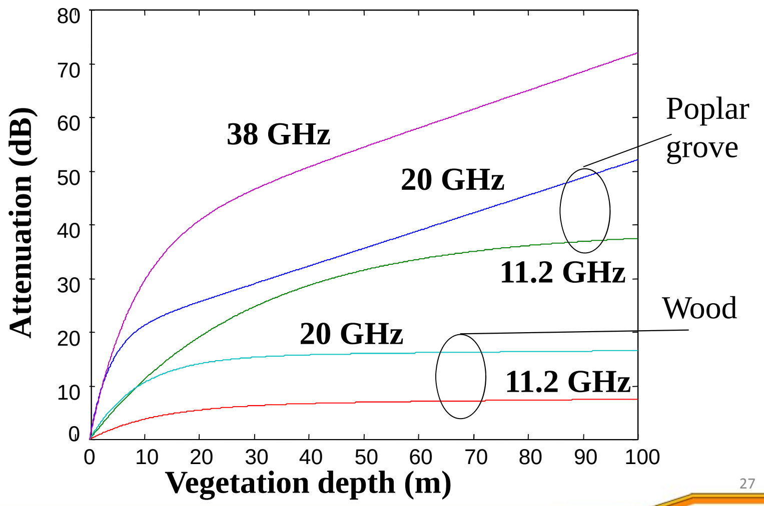
$$A_{VEG} = -\left(R_\infty d + k\left(1 - e^{-\frac{(R-R_0)}{k}d}\right)\right)$$

R_0 : initial rate of attenuation
R_{oo} : final rate of attenuation
k : final offset

2.1. **P-T-MP PLANNING SYSTEM** *(23):*

DEGRADATION MECHANISM (22)

ATTENUATION BY VEGETATION (4)



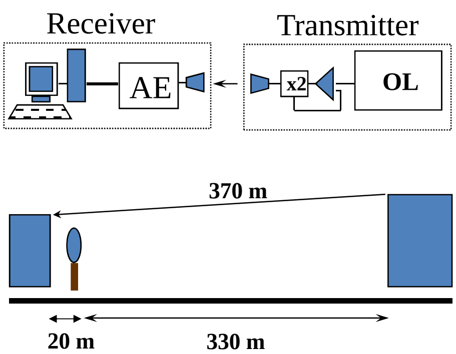
2.1. **P-T-MP PLANNING SYSTEM** *(24):*

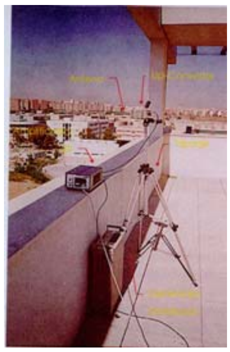
DEGRADATION MECHANISM (23)

ATTENUATION BY VEGETATION (5)

Real case

Propagation measurements for a LMDS 28 GHz link





2.1. **P-T-MP PLANNING SYSTEM** *(25):*

DEGRADATION MECHANISM (24)

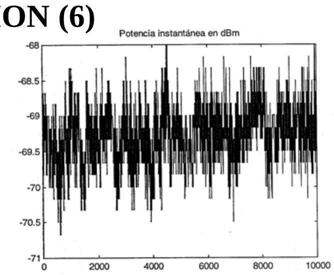
ATTENUATION BY VEGETATION (6)

Case A: line of sight

Vertical polarization

$$\overline{P} = -60{,}6577\,dBm$$

$$\sigma = 0{,}2777\,dBm$$

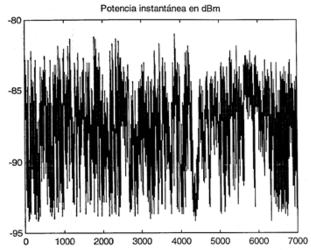


Caso B: a tree, obstruction

Vertical polarization

$$\overline{P} = -85{,}323\,dBm$$

$$\sigma = 3{,}904\,dBm$$



1 tree ¡25 dB!

2.1. **P-T-MP PLANNING SYSTEM** *(26):*

DEGRADATION MECHANISM (25)

DIFFRACTION IN BUILDINGS (1)

Mathematic models based in geometric models (models based on optic are not valid for millimetric frequencies).

GTD (General Theory of Diffraction). Total diffraction is the addition of every diffracted beams. Buildings are modelled as semi-infinite fronts perfectly conductives finished in a knife-edge.

UTD (Uniform General Theory of Diffraction). It models the diffraction of a plane wave in an edge with oblique incidence.

2.1. P-T-MP PLANNING SYSTEM *(27):*

DEGRADATION MECHANISM (26)

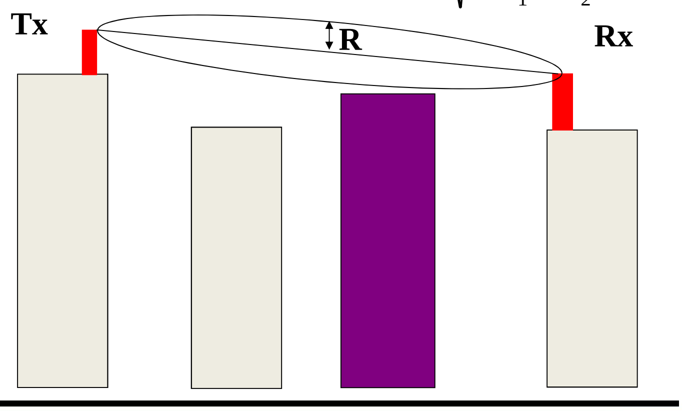
DIFFRACTION IN BUILDINGS (2)

First Fresnel area

$$R = \sqrt{\lambda \frac{d_1 d_2}{d_1 + d_2}}$$

R_{26}=3,8 m

d = 5 km



2.1. P-T-MP PLANNING SYSTEM (28):

3. THEORETICAL CELLULAR PLANNING

3.1. Channeling.

3.2. Cellular shapes.

3.3. Frequency plan.

3.4. Cellular sizes.

- **Power balance: link planning**
- **Quality if service**
- **User density**

2.1. P-T-MP PLANNING SYSTEM (29):

THEORETICAL CELLULAR PLANNING (1)

CHANNELING

Regulating organization assigns frequency plans to use in every service, defining:

- **Frequency band.**
- **Division between channels and bandwidth per channel.**
- **Channel assignment for downstream and upstream**

This channeling is going to fix the basic work parameters to realize a correct system planning .

2.1. P-T-MP PLANNING SYSTEM (30):

THEORETICAL CELLULAR PLANNING (2)

CELL SIZES

There are 3 main factors to establish the correct cell size.

1. LINK CALCULUS
   - Power balance
   - Fainting margin
2. QUALITY OF SERVICE
   - Carrier to noise ratio (C/N)
   - BER
   - ATM quality parameters
3. USER DENSITY

2.1. P-T-MP PLANNING SYSTEM (31):

THEORETICAL CELLULAR PLANNING (3)

POWER BALANCE:LINK CALCULUS (1)

1. WE CONSIDER LINE OF SIGHT ⟶ $A_{VEG} = A_{DIFF} = 0$

2. VERTICAL POLARIZATION

Transmission equation:

$Pr=Pt+Gt-A_{FS}-A(d)+Gr$

where A(d) is the addition of previously calculated attenuations

$A(d)=(A_{ATM}+A_{LL}+A_{N}+A_{SNOW})xd$

Received power must be bigger than the receiver sensitivity.

2.1. P-T-MP PLANNING SYSTEM (32):

THEORETICAL CELLULAR PLANNING (4)

POWER BALANCE:LINK CALCULUS (2)

Receiver sensitivity depends on the modulation (QPSK, 16QAM, 64QAM)

- **QPSK receiver sensitivity (ETSI)**

	10 GHz	26 GHz	
7 MHz	-85 dBm	-88 dBm	$P_{tx}(26)=+19$ dBm
14 MHz	-82 dBm	-85 dBm	$P_{tx}(10)=+20$ dBm

If we suppose this P_{tx}, G_T= 15 dBi, G_R=35 dBi, we obtain

- **Maximum cell size**

MD: 6 dB/km
MD: 3 dB/km

	26 GHz	10 GHz
14 MHz	3.6 km	7,7 km
7 MHz	3.2 km	9 km

2.1. P-T-MP PLANNING SYSTEM (33):

THEORETICAL CELLULAR PLANNING (5)

POWER BALANCE:LINK CALCULUS (3)

Loss are **not** deterministics, so the sizing of cells must be done for an specific availability of the link and we have to predict a fanting margin.

Fainting margin for a 5 km and 28 GHz link in different rain areas and polarizations (dB)						
Availability	**C area**		**K area**		**P area**	
(%)	V	H	V	H	V	H
99	1.2	1.4	3.1	3.7	8.2	10.3
99,9	4.1	4.8	9.9	12	26.1	32.9
99,99	11.5	12.9	25.3	30.8	68.1	85.5
99,999	22.6	25.5	53.9	65.8	145.9	183.9

2.1. P-T-MP PLANNING SYSTEM (34):

THEORETICAL CELLULAR PLANNING (6)

QUALITY OF SERVICE (1)

In this case, the size of cell is fixed by quality of service parameters

1. Carrier to noise ratio (C/N)

$$\left(\frac{C}{N}\right)_{dB} = C(dBm) - N(dBm)$$

$$C(dBm) = PIRE + G_{rx} - A(d) - A_{FS}$$

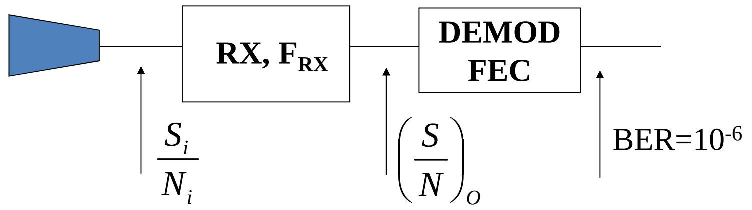
$$N(dBm) = 10\log\left(KT_0B\right) + F_{rx} + 30$$

2.1. P-T-MP PLANNING SYSTEM (35):

THEORETICAL CELLULAR PLANNING (7)

QUALITY OF SERVICE (1)

2. Demoludator output BER



BER known limit $\longrightarrow \frac{E_b}{N_0} \longrightarrow \left(\frac{S}{N}\right)_O \longrightarrow S_i$

(it depends on the modulation) (knowing N_i)

2.1. P-T-MP PLANNING SYSTEM (36):

THEORETICAL CELLULAR PLANNING (8)

Example: QPSK

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_o}}\right) \longrightarrow \frac{E_b}{N_o} \cong 10dB \longrightarrow \frac{E_b}{N_o} = \frac{S}{N}\cdot\frac{W}{R}$$

where W: bandwidth $\quad W = \frac{1+\alpha}{T_s} = \frac{1+\alpha}{2T_b}$

R: information rate $\quad R = \frac{1}{T_b}$

So:

$$\left(\frac{S}{N}\right)_i = \frac{E_b}{N_0} + 10\log\left(\frac{R}{W}\right) = 11.2494\Big|_{\alpha=0,75}$$

Finally:

$$S_i = \left(\frac{S}{N}\right)_O + F_{RX} - 10\log(KTB)$$

2.1. P-T-MP PLANNING SYSTEM (37):

THEORETICAL CELLULAR PLANNING (9)

M-QAM

$$P_b = \frac{2}{k}\left(1-\frac{1}{\sqrt{M}}\right)\times erfc\left(\frac{3}{2(M-1)}k\gamma_b\right)\times\left(1-\frac{1}{2}\left(\frac{1}{\sqrt{M}}\right)\right)\times erfc\left(\sqrt{\frac{3}{2(M-1)}k\gamma_b}\right)$$

Where:

$M=2^k$,

k: number of bits by symbol

γ_b= average SNR by bit

$$erfc(x) = 2Q\left(x\sqrt{2}\right)$$

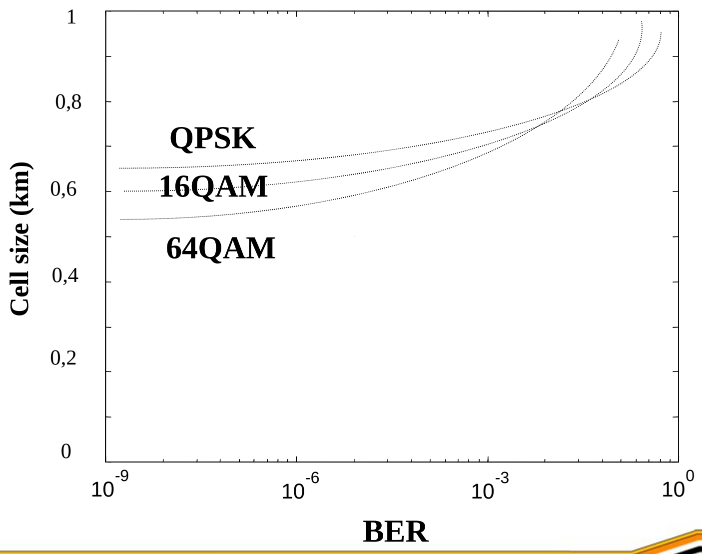
$$Q(x) = \frac{1}{2}erfc\left(\frac{x}{\sqrt{2}}\right)$$

In this case, $T_S \cong k \cdot T_b$ (adapted receiver)

the relation between Q(x) and erfc(x) is the next:

2.1. P-T-MP PLANNING SYSTEM (38):

THEORETICAL CELLULAR PLANNING (10)



2.1. P-T-MP PLANNING SYSTEM (39):

THEORETICAL CELLULAR PLANNING (11)

ATM QUALITY OF SERVICE PARAMETERS

It is possible to relate BER to own parameters from ATM networks like:

Cell loss ratio (CLR): relationship between cell loss and total cell transmitted.

Cell error ratio (CER): relationship between cell error received and total cell transmitted.

→ **ITU-T I.356 recommendation**

2.1. P-T-MP PLANNING SYSTEM (40):

THEORETICAL CELLULAR PLANNING (12)

USER DENSITY

If the user density is high, it is possible that you have to define again the cell size.

- Restriction in avaliable **bandwidth**.
- Restriction in WLL **equipment**.

- To use a more efficient modulation
- To increase the number of used frequencies
- To increase the cell sizing

If it is not possible → To reduce the cell size
To increase the number of base stations

2.1. P-T-MP PLANNING SYSTEM (41):

THEORETICAL CELLULAR PLANNING (13)

USER DENSITY

Main measurements are:

- **Number and building density (N_a)**
- **Expected penetration (%P).**
- **Expected traffic by user (T_{max}).**

$$\text{Number of cells}=\frac{N^{o}\ de\ canales\ necesarios/celda}{N^{o}\ de\ canales\ ofrecidos/celda}$$

$$\text{Number of needed channels } = E\left[N_a\cdot\%P\cdot T_{\max}\right]$$

$$P_B=\frac{A^N/N!}{\sum_{n=0}^{N}A^n/n!}$$

2.1. P-T-MP PLANNING SYSTEM (42):

THEORETICAL CELLULAR PLANNING (14)

USER DENSITY

Examples: REUNION, NORTEL NETWORKS

LMDS system to 28 GHz, W=10 MHz, 99,99%

	1 carrier 4QAM	1 carrier 16QAM	1 carrier 64QAM	2 carriers 64QAM	3 carriers 64QAM	4 carriers 64QAM
Coverage (km)	4.5	3,2	2,2	1,7	1,5	1,3
ATM capacity (Mbps)	13,7	27,4	41,1	82,3	123,4	164,5
Capacity/km²	0,9	3,4	10,8	36,7	68,9	123,9

2.1. P-T-MP PLANNING SYSTEM (43):

STATISTIC MODEL (1)

4. STATISTIC MODEL

Radio channel properties are changeable, so the *descriptions* must be *statistics*.

To do this, we must realice a measurement joint that will be processed to extract the parameter we need to model the channel behavior.

From the statistics, we will realize a hypothesis test to determinate what type of distribution models the channel we are evaluating.

2.1. P-T-MP PLANNING SYSTEM (44):

STATISTIC MODEL (2)

PROBABILITY DENSITY EQUATIONS

Long term fainting

We consider as a **normal distribution**

$$f_p(P) = \frac{\ln 10}{20\sigma\sqrt{2\pi}} \exp\left[-\frac{1}{2\sigma^2} \left(\ln \frac{10^{\frac{P-30}{20}}}{\sqrt{K}} - \mu \right)^2 \right]$$

$$\mu = \frac{1}{N} \sum_{i=1}^{N} \ln E_i$$

$$\sigma^2 = \frac{1}{N} \sum_{i=1}^{N} \left(\ln E_i - \mu \right)^2$$

2.1. P-T-MP PLANNING SYSTEM (45):

STATISTIC MODEL (3)

PROBABILITY DENSITY FUNCTIONS

Short term fainting

Several types of distribution: **Nakagami-Rice.** We use this when we have line of sight and exist one or many predominant contributions.

$$f_p(P) = \frac{10^{\frac{P-30}{10}} \ln 10}{20K\sigma^2} \exp\left(-\frac{10^{\frac{P-30}{20}} + KC^2}{2K\sigma^2} \right) I_0\left(-\frac{10^{\frac{P-30}{20}} C}{\sigma^2 \sqrt{K}} \right)$$

$$I_0(x) = \sum_{i=1}^{\infty} \frac{(x/2)^{2i}}{\Gamma(i+1)^2} \qquad C = \frac{1}{N} \sum_{i=1}^{N} E_i$$

$$\sigma^2 = \frac{1}{2N} \sum_{i=1}^{N} E_i^{\,2} - \frac{1}{2N^2} \left(\sum_{i=1}^{N} E_i \right)^2$$

2.1. P-T-MP PLANNING SYSTEM (46):

STATISTIC MODEL (4)

HYPOTHESIS TEST

It allows to decide what distribution models more easier the channel behavior.

Two types:

Parametrics : SMIRNOV-KOLMOGOROV test. It calculates the difference between theorical distribution functions and empiric ones.

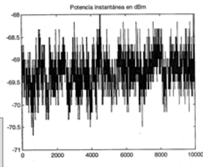
No parametrics: **Pearson χ^2** test. It realizes the comparison between theorical and empiric distribution functions along the sample space, avoiding punctual situations.

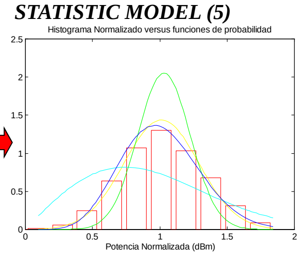
2.1. P-T-MP PLANNING SYSTEM (47):

STATISTIC MODEL (5)

EXAMPLE: vegetation model

	Free space	Vegetation
NORMAL	0,1189	**0,0450**
RAYLEIGH	0,1382	0,1152
NAKAGAMI-RICE	0,2245	0,1449
NAKAGAMI	**0,0915**	0,0908



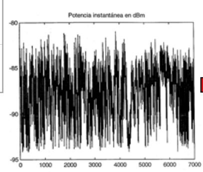


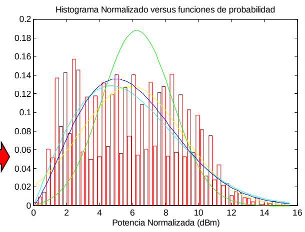
Normal

Rayleigh

Nakagami-Rice

Nakagami





WIRELESS POINT-TO-MULTIPOINT SYSTEMS

2.1. P-T-MP planning system
2.2. P-T-MP components
2.3. Manufacturers and distributors.
2.4. Market perspectives.
2.5. Trials.
2.6. Future trends.

P-T-MP components

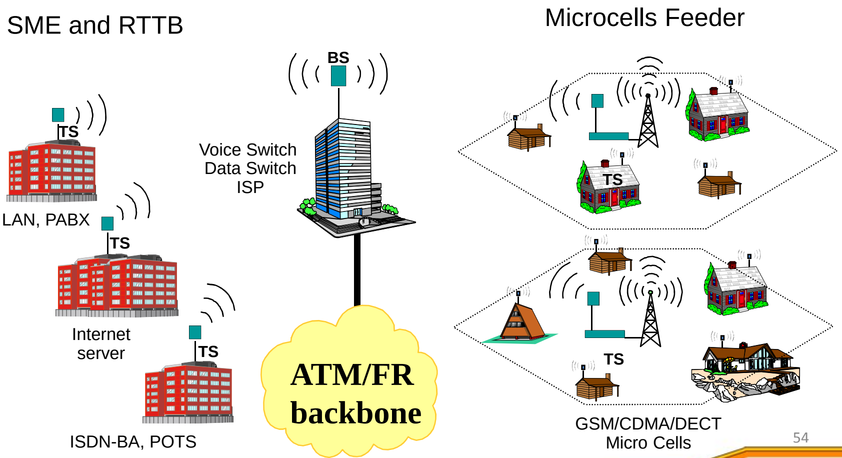
1. INTRODUCTION

2. BASE STATION
   - 2.1. Block diagrams
   - 2.2. Radio equipment
   - 2.3. Interface with the main network

3. RADIO INTERFACE

4. USER EQUIPMENT
   - 4.1. Block diagram
   - 4.2. State of the art technology
   - 4.3. Receiver equipment

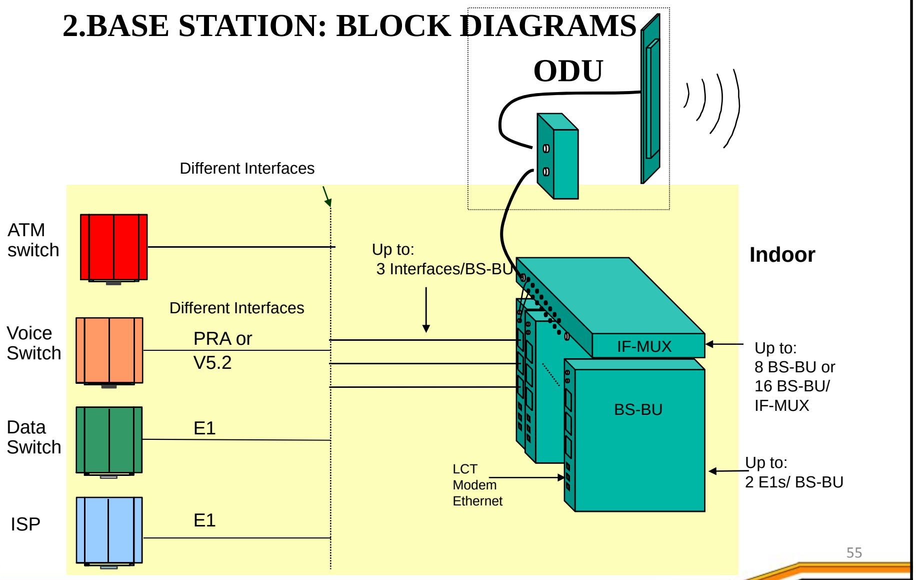
1. INTRODUCTION
PMP system architecture



2.2. P-T-MP COMPONENTS (2):

BASE STATION (1)

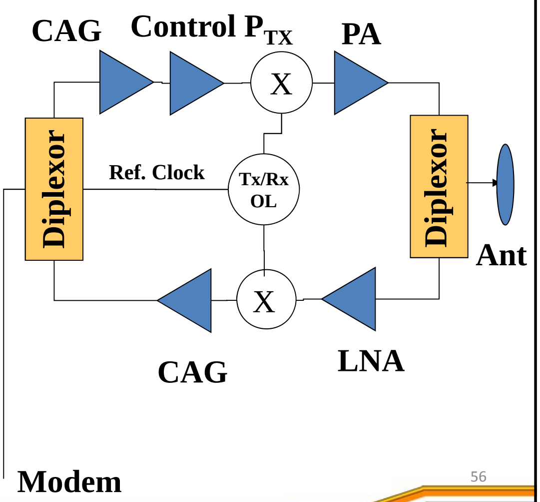
2.BASE STATION: BLOCK DIAGRAMS



2.2. P-T-MP COMPONENTS (3):

BASE STATION (2)

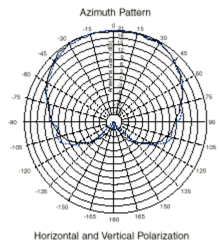
RADIO EQUIPMENT: ODU



2.2. P-T-MP COMPONENTS (4):
BASE STATION (3)

ANTENNAS

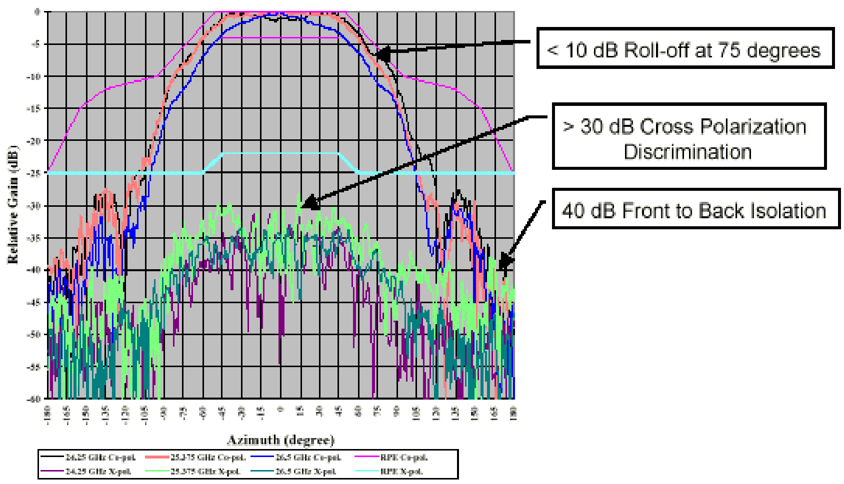
Omni-directional
Typical gain: 6-15 dBi
Bandwidth: 1 GHz
PD: 20 dB
“mushroom” antenna



Sectorial horns
Typical gain: 15-24 dBi
Sectors of 30, 45 and 90º
PD: 25 dB

2.2. P-T-MP COMPONENTS (5):
BASE STATION (4)

ANTENNAS



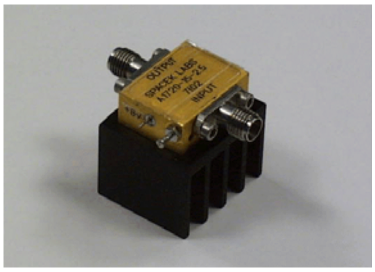
2.2. P-T-MP COMPONENTS (6):

BASE STATION (5)

STATE OF THE ART TECHNOLOGY:

AMPLIFIERS

Power amplifiers (SSPA)



G > 30 dB
NF: 8dB
P_{-1dB} > 1 W (30 dBm)

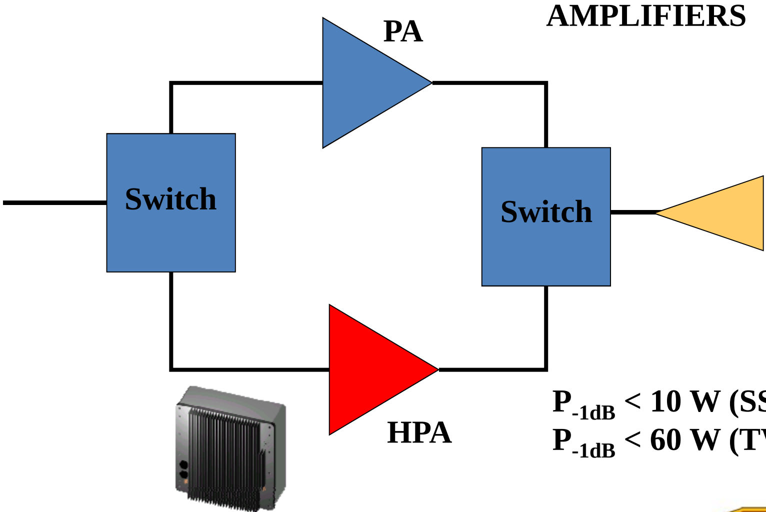
Low noise amplifiers (LNA)
G > 25 dB
NF: 5 dB (4 GHz)
P_{-1dB} > 23 dBm

2.2. P-T-MP COMPONENTS (7):

BASE STATION (6)

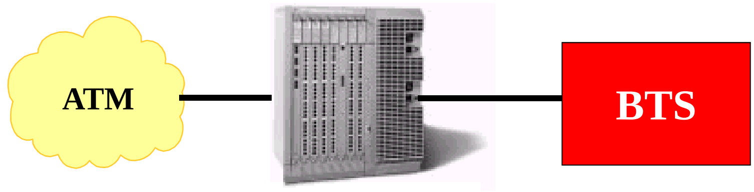
STATE OF THE ART TECHNOLOGY:

AMPLIFIERS



P_{-1dB} < 10 W (SSPA)
P_{-1dB} < 60 W (TWT)

INTERFACE WITH THE MAIN NETWORK



- it provides the bus of ATM data control
- SNMP routing for network management
- IP network connections
- syncronism extraction

ATM standard defines many ways to adapt traffic to ATM structures

AAL1:

• This is for constant traffic that doesn't permit cell loss, it can be used to transmit voice and data.

AAL5:

• This is for traffic that isn't affected by signal delays and is more tolerant to cell loss (UBR variations, nrtVBR, ABR)

• It can be used for voice and data, but mainly for data (VoIP, IP over ATM).

AAL2:

• Similar to AAL1 but compress and makes optimal BW for voice

• ideal if the network is mainly for voice.

2.2. P-T-MP COMPONENTS (10):
RADIO INTERFACE (1)

3. RADIO INTERFACE

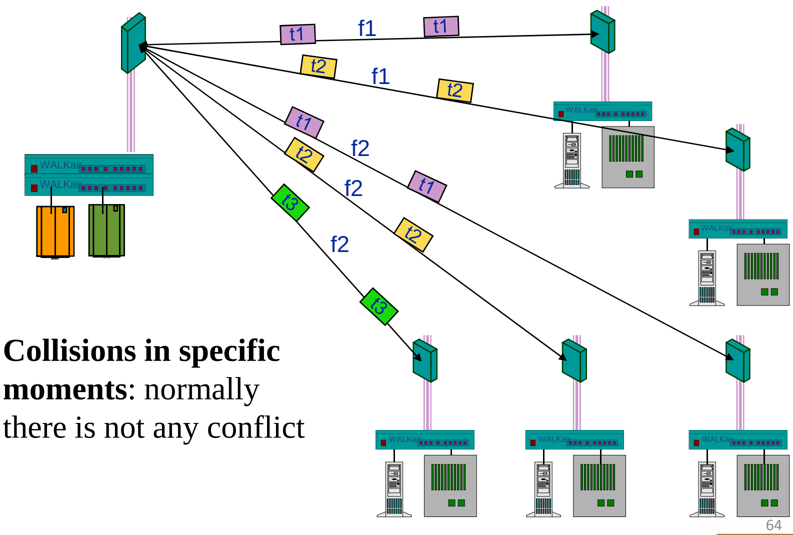
Existing systems use an access sytem that combines time and frequency multiplexing.

TDM/FDM/TDMA

Base station trasmits in many carriers using several radio equipments. Every carrier signal provide several time intervals, that are assign to the users according to the traffic needs.

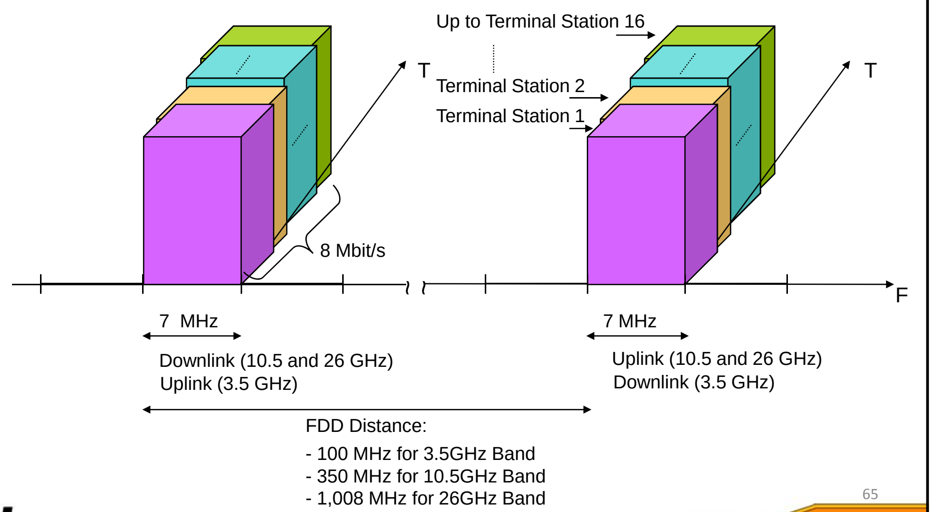
Users share the same bandwidth accessing to the station only when BS provides them the token.

2.2. P-T-MP COMPONENTS (11):
RADIO INTERFACE (2)



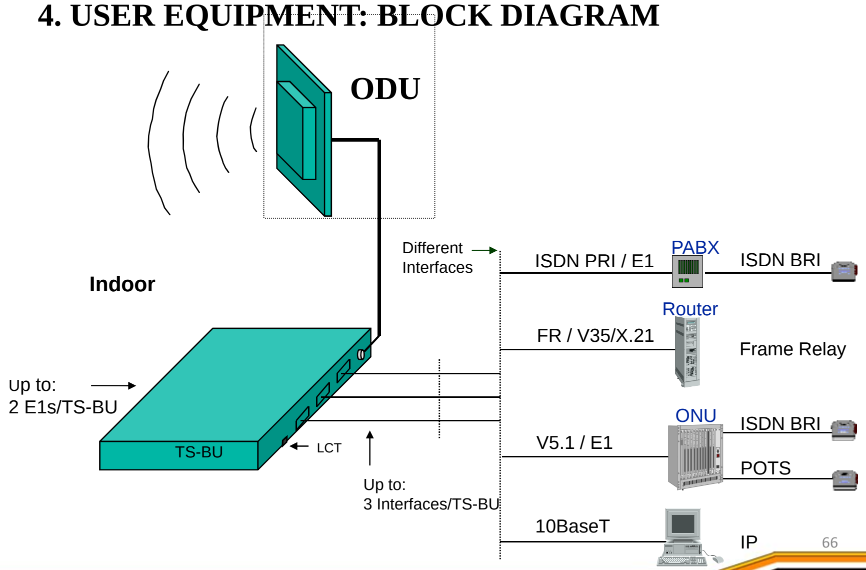
Collisions in specific moments: normally there is not any conflict

2.2. P-T-MP COMPONENTS (12):
RADIO INTERFACE (3)



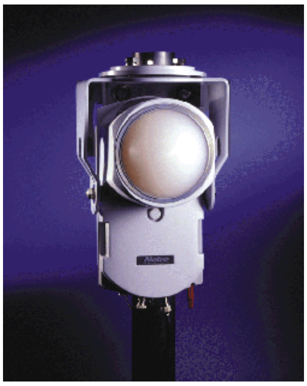
2.2. P-T-MP COMPONENTS (13):
USER EQUIPEMT (1)

4. USER EQUIPMENT: BLOCK DIAGRAM



2.2. P-T-MP COMPONENTS (14):
USER EQUIPMENT (2)

STATE OF THE ART TECHNOLOGY: ODU



- High integration antenna-converter
-Output power: 19-24 dBm
- Receiver sensitivity < -80 dBm

2.2. P-T-MP COMPONENTS (15):
USER EQUIPMENT (3)

STATE OF THE ART TECHNOLOGY :ANTENNAS

Cassegrain reflector
Typical gain: 30-35 dBi
Beam width: 2º-7º

Horn-Lens
Typical gain: 30-35 dBi
Beam width: 2º-7º
Better NLPS and FB
Worst ecological impact

2.2. P-T-MP COMPONENTS (16):
USER EQUIPMENT (4)

USER INDOOR EQUIPMENT

-It encapsulates the traffic in ATM cells.
- Interfaces for E1/T1 and 10baseT (LAN) port.
- It transmits and recieves the IF signals from/to ODU
- It provides supply to ODU
- Telemetry
- SNMP agent for network management
- Actually AAL5 for VBR-nrt traffic. In the next implementations, AAL2 for VBR-rt traffic.

WIRELESS POINT-TO-MULTIPOINT SYSTEMS

2.1. P-T-MP planning system
2.2. P-T-MP components
2.3. Manufacturers and distributors
2.4. Market perspectives.
2.5. Trials.
2.6. Future trends.

2.3. MANUFACTURERS AND DISTRIBUTORS (1): INTRODUCTION

MANUFACTURERS AND DISTRIBUTORS

Objective: To show some of the access system manufacturers, both wireless access and wideband distribution systems. It has been producing a huge amount of merger and acquisitions companies, what shows the start of a great business and companies that want to bet in it are taking position.

1998: **Nortel Networks** acquires **Broadband Networks**
1999: **Siemens** adquires **Floware (10%)**
2000: Marconi adquires **Bosch** public networks division
2000: Alcatel adquires **Newbridge Networks**
2001: Alvarion buys **Breezecomm**
2003: Tripoint Global adquires **Gabriel Networks**
2005/7: Cisco adquires **Airespace y Navini**
2008: Alvarion y Nortel develop Wimax and LMDS solutions
2010: HTC launches cellular mobile with Wimax technology
2011: 802.16m standard approval (**WiMaX 2**)
2012: **Nokia Siemens Networks**, developed the first 4G mobile in 2,6 GHz broadband pilot with TD-LTE (Wimax) technology in Murcia, Spain

2.3. MANUFACTURERS AND DISTRIBUTORS (2):

NETRO (1)

AirStar

- System that works in 3.5, 10.5 and 26 GHz bands.
- TDM/FDMA/TDMA access
- Aplications: Voice, Data, n-RDSI Frame-Relay, PABX
- Owner protocol based on ATM that applies QoS parameters.
- 7 or 14 MHz channeling and QPSK modulation (4xE1)
- 45º and 90º sectors

http://www.netro-corp.com

2.3. MANUFACTURERS AND DISTRIBUTORS (3):

NETRO (2)

- **Coverage:**

26 GHz → 4 km (99,999%) 7 km (99,99%)
10 GHz → 16,2 km (99,999%) 27 km (99,99%)

- **Synchronism are fixed by ATM**. Base station transmits the modulated clock and users connect to it. It's essential because of the access protocol (CellMac). System has very stable backup clocks just in case the network losts the connection.

- **Huge amount of installed networks → tested technology**

2.3. MANUFACTURERS AND DISTRIBUTORS (4):

ALVARION (1)

BreezeAccess VL

- Frequencies: 5.725 - 5.850 GHz, 5.47 - 5.725 GHz, 5.15 - 5.35 GHz, 4.9 - 5.1 GHz

- TDD access

- Distance between channels 20 MHz

- Frequency resolution 10 MHz

- Output power:
-10 dBm to 21 dBm (BS)
-10 dBm to 21 dBm (TU)

-90º, 120º and 360º sectors

-LOS and NLOS

P-T-MP equipment

http://www.alvarion.com

2.3. MANUFACTURERS AND DISTRIBUTORS (5):

ALVARION (2)

BreezeAccess VL

Sensitivity (dBm)	-89	-88	-86	-84	-81	-77	-73	-71
Modulation level	1	2	3	4	5	6	7	8

- Modulation:
OFDM (BPSK, QPSK, 16QAM, 64 QAM)

- Network management:
SNMP agent BreezeAccess owner equipment

- Gains of the antennas:
16 dBi (90º), 15 dBi (120º), 8 dBi (360º)

2.3. MANUFACTURERS AND DISTRIBUTORS (6):

ALVARION (3)

BreezeAccess LB

- Frequencies: 5.725 - 5.850 GHz, 5.47 - 5.725 GHz, 5.15 - 5.35 GHz, 4.9 - 5.1 GHz

- Power transmission: 20 dBm

- Gain 28 dBi

- 4,5º beam width antennas

- Rate transmission: 36-72 Mbps

- LOS and NLOS

P-T-P equipment

2.3. MANUFACTURERS AND DISTRIBUTORS (7):

P/COM

AirPro

- **Coverage until 10 km**
- **Work frequencies: all allowed bands from 10 to 38 GHz**
- **Several modulation types: QPSK, 16 y 64QAM**
- **Capacity until 85E1/sector, 24 sectors/BS, multi-service**
- **TDM/FDMA/TDMA access**
- **SNMP over HP Openview**

System	10GHz	24GHz	26GHz	28GHz	31GHz	38GHz
Frequency Range	10.15-10.65 GHz	24.25–25.25 GHz	24.5–26.06 GHz	27.5–31.225 GHz	31.0–31.300 GHz	38.6–40.0 GHz
TR/Separation	350 MHz	800 MHz	1008 MHz	FCC & Industry Canada	225 MHz	700 MHz
Transmitter	10GHz	24GHz	26GHz	28GHz	31GHz	38GHz
QPSK	14 dBm	22 dBm	22 dBm	22 dBm	22 dBm	20 dBm
16-QAM	12 dBm	20 dBm	20 dBm	20 dBm	20 dBm	18 dBm
64-QAM		18 dBm	18 dBm	18 dBm	18 dBm	16 dBm
Receiver @8 Mbps	10GHz	24GHz	26GHz	28GHz	31GHz	38GHz
QPSK	–87 dBm	–87 dBm	–87 dBm	–87 dBm	–86 dBm	–86 dBm
16-QAM	–83 dBm	–83 dBm	–83 dBm	–83 dBm	–82 dBm	–82 dBm
64-QAM	–77 dBm	–77 dBm	–77 dBm	–77 dBm	–76 dBm	–76 dBm

2.3. MANUFACTURERS AND DISTRIBUTORS (8):

NORTEL NETWORKS

NORTEL NETWORKS: REUNION

- **Coverage until 35 km**
- **Work frequencies: all allowed bands from 2 to 42 GHz**
- **Several modulation types: QPSK, 16 y 64QAM**
- **Capacity: STM-1/sector, 16 sectors/BS**
- **TDM/FDMA/TDMA access**
- **SNMP over owner platform**
- **User equipments allow until 4E1+1 10Base-T**

2.3. MANUFACTURERS AND DISTRIBUTORS (6):

SIEMENS WALKAIR (1)

SIEMENS WALKAIR

- **3.5 GHz, 10.5 GHz and 26GHz bands**
- **Coverage**
  - **10 km to 3.5GHz and 10.5 GHz**
  - **3 Km in 26GHz band**
- **Distance between channels 1.75 MHz**
- **Modulation efficiency: 2.5 bits/s/ Hz**
- **TDMA /Multi-carrier/FDD**
- **Bandwidth dinamic assignment**
- **Frequency re-using**
- **SNMP agent**
- **Multiservice**
- **Modular**

2.3. MANUFACTURERS AND DISTRIBUTORS (7):

SIEMENS WALKAIR (2)

- It assures BER< 10^{-9}
- Channel equalization and Trellis codification
- 99.999% availability
- Optionally, it allows equipment redundancy.
- adaptive frequency to reduce CIR.

	By carrier	By sector	By cell (BS)
Capacity without frequency re-using	2xE1	16, 32, 32xE1	96,192, 384xE1
N° of terminal stations(Max.)	16, 16, 16	128, 256, 256	768, 1536, 3072
N° carriers (Max)*		8, 16, 16	48, 96, 192
N° Sectors			4/6, 4/6, 4,/8/12
Bandwidth (Max.)*	1.75 MHz	2x14, 2x28,2x28 MHz	2x84,2x168,2x336 MHz
Frequency re-using factor			Up to 2, 2, 3 **

* Limitated by hardware, not by bandwidth

** Capacity can be increased by 50% using several polarizations

2.3. MANUFACTURERS AND DISTRIBUTORS (8):

MOTOROLA(1)

- Frequencies:5.47 - 5.725 GHz

- Gain 7 dBi

- Rate transmission: 20 Mbps

- LOS and NLOS

-Allowed protocols: IPV4, UDP, TCP, ICMP, Telnet, HTTP, FTP, SNMP

-Network management: HTTP, FTP, SNMP version 2c

Base station

Advantage AP
PIRE: 30 dBm

P-T-MP equipment

User

Advantage SM
PIRE: Adjustable

Parámetro	P-MP	P-P	Malla	Desde y hacia cualquier punto
Máx. potencia media pire (1)	36 dBm	36 dBm	33 dBm	33 dBm
Máx. densidad media de potencia pire	23 dBm/MHz	23 dBm/MHz	20 dBm/MHz	20 dBm/MHz
Rango TPC	12 dB	12 dB	12 dB	12 dB

2.3. MANUFACTURERS AND DISTRIBUTORS (9):

MOTOROLA(2)

PTP 58300 & PTP 54300

P-T-P equipment

- Frequencies: 5.725 GHz–5.875 GHz 5.470 GHz–5.725 GHz

-Channel bandwidth: 15 MHz

- Channel selection: Dynamic Frequency Selection (i-DFS) or manual selection

- Antenna: 9º beam width and 23 dBi of gain

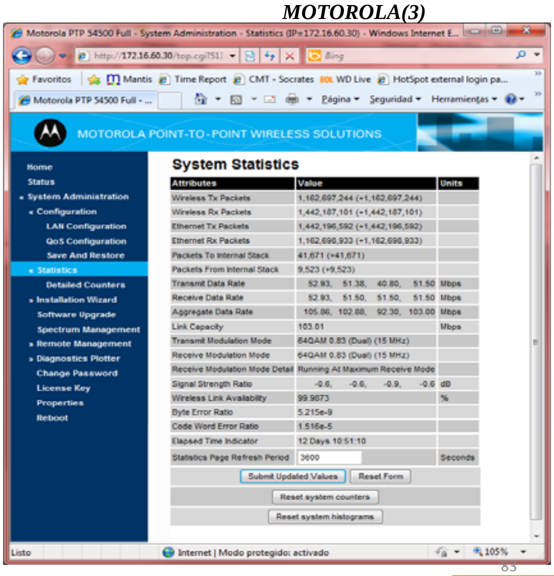
- Dynamic modulation, between BPSK and 64QAM

- Security and encryption: owner model and optional 128 and 256 AES

2.3. MANUFACTURERS AND DISTRIBUTORS (10): MOTOROLA(3)

PTP 54500 data

- **99,987% disponibility**
- **Bandwidth: 15 MHz**
- **Modulation: 64QAM**
- **Nowadays working!!**



2.3. MANUFACTURERS AND DISTRIBUTORS (11): OTHERS

MARCONI Communications:http://www.marconi.com
Alcatel: http://www.alcatel.com
Telaxis Communications (Millitech): http://www.telaxis.com
ADC Teledata: http://www.adc.com
Tadiran: http://www.tadiran-com.co.il
Alvarion: http://www.alvarion.com
Airspan: http://www.airspan.com
Dudley Labs: http//www.dudleylab.com
Procera Networks: http//www.p-com.com
SR Telecom: http://www.srtelecom.com/
UT Starcom: http://www.utstarcom.com/
ArrayComm: http://www.arraycomm.com

2.3. MANUFACTURERS AND DISTRIBUTORS (12):

INTEGRATION SYSTEMS (1)

INTEGRATION SYSTEMS

The problem of WLL turn-key system manufacturers is the fact that the technologies are mostly owner technologies, so the operator is related to manufacturers.

Sometimes, it can be interesting to break this chains and to use an integration system. Manufacturers produce and assemble sub-systems(amplifiers, oscillators, filters,….) that create radio unities of WLL systems: ODU's.

→ For example: **repeaters**

2.3. MANUFACTURERS AND DISTRIBUTORS (13):

INTEGRATION SYSTEMS (2)

MMCOMM Inc: **http://www.mmcom-inc.com**
M/ACOM: **http://www.macom.com**
REMEC: **http://www.remec.com**
DBS NARDA: **http://www.nardamicrowave.com**
MITEQ: **http://www.miteq.com**
QUINSTAR: **http://www.quinstar.com**
SPACEK LABS: **http://www.spaceklabs.com**
FARRAN: **http://www.farran.com**
ANDREW: **http://www.andrew.com**
TRIPOINT GLOBAL: **http://www.tripointglobal.com**
DORADO: **http://www.dorado-intl.com**
FLANN: **http://www.flann.com/**

WIRELESS POINT-TO-MULTIPOINT SYSTEMS

2.1. P-T-MP planning system
2.2. P-T-MP components
2.3. Manufacturers and distributors.
2.4. Market perspectives.
2.5. Trials.
2.6. Future trends.

MARKET ISSUES

1. INTRODUCTION
2. EVOLUTION OF THE NUMBER OF USERS
3. COMPARATIVE CABLE-WLL

2.4. MARKET ISSUES (1):

INTRODUCTION (1)

INTRODUCTION

According to analysts, WLL system development has just starting

In markets where is allowed, **new operators** offer, basically, two types of services.

• Internet connections (Wireless ISP)
• Distribution of video, voice and data systems (LMDS)

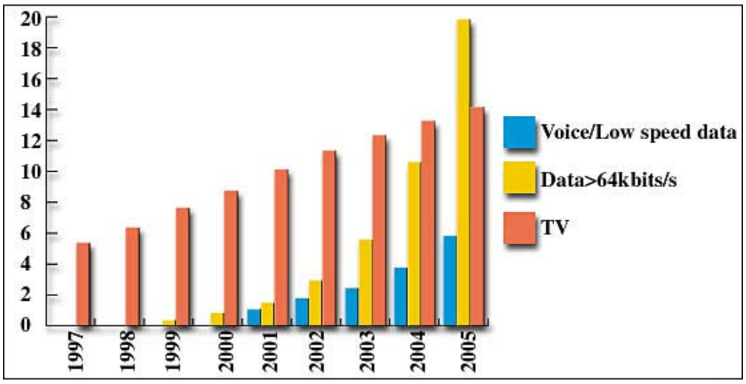
On other hand, **cellular mobile operators** have found in wireless access systems (FWA) an opportunity to access to fixed segment.

2.4. MARKET ISSUES (2):

EVOLUTION OF NUMBER OF USERS

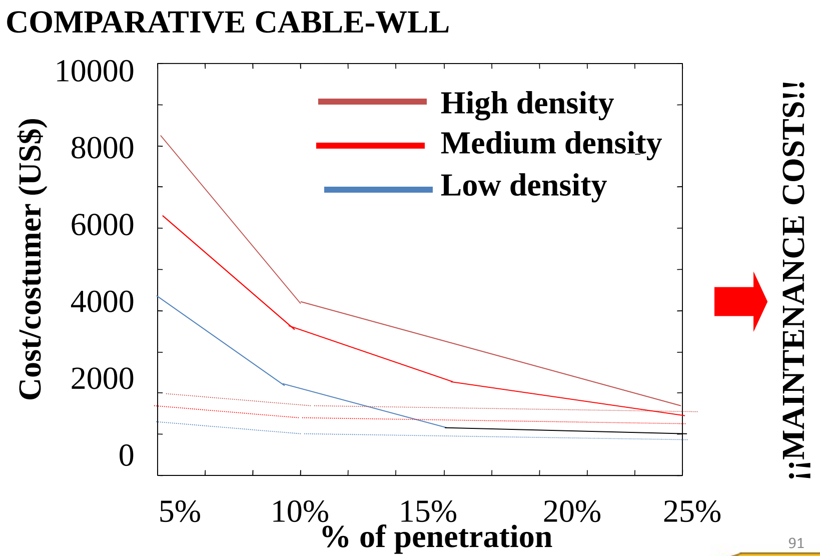
EVOLUTION OF THE NUMBER OF USERS

According to analyst, the demand growth in WLL systems will be dominated by data services (medium and high capacity and the video distribution ones).



2.4. MARKET ISSUES (3):

COMPARATIVE CABLE-WLL



WIRELESS POINT-TO-MULTIPOINT SYSTEMS

2.1. P-T-MP planning system
2.2. P-T-MP components
2.3. Manufacturers and distributors.
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TRIALS

COLLSEROLA

High capacity internet connection (2 Mbps) digital TV broadcasting

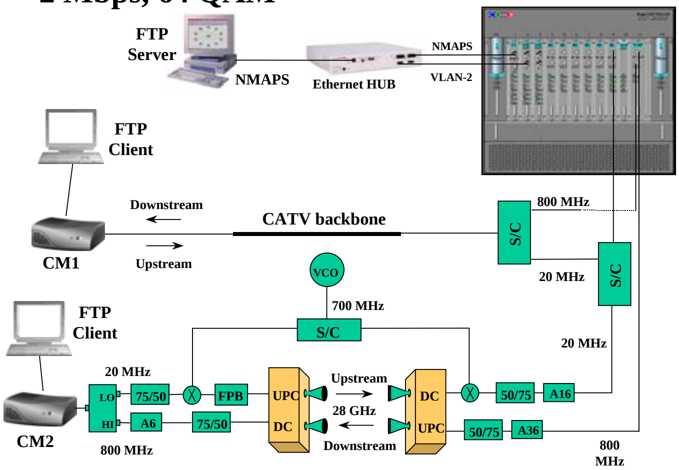
Objetives:

•To save trips to central assistances : tele-rehabilitation
•Distance learning networks: tele-education

Stage 2: 34 Mbps links (working)

UPV-FRG

- **bidirectional transmissions using Com21 cable-modems**
- **2 Mbps, 64 QAM**



2.5. TRIALS (3):

CRABS

ACTS Project 215
Cellular Radio Access for Broadband Services

• They propose architecture and LMDS service systems for 40 GHz besides of planification and medium access (Report D2P1B).

• trials in Norway, Greece, Italy and UK. DVB video distribution and Internet access (Report D4P4).

• Deliverable D1P2: level interest and user satisfaction tests.

Lesson 2: point-to-multipoint wireless planning systems

WIRELESS POINT-TO-MULTIPOINT SYSTEMS

2.1. P-T-MP planning system
2.2. P-T-MP components
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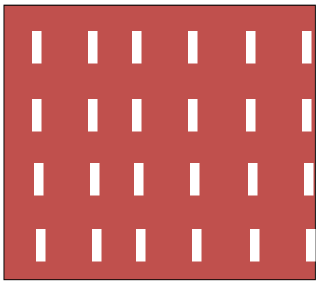
2.6. FUTURE TRENDS (1):

FLAT ANTENNA

FUTURE TRENDS

SMART ANTENNAS

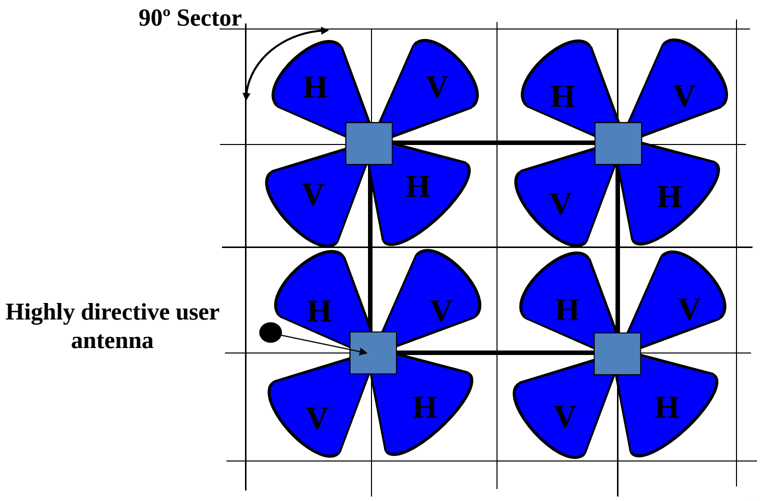
- "patch" antennas array
- beam electronically reconfigurable
- small sizes → low environmental impact



2.6. FUTURE TRENDS (2):

RECONFIGURABLE BEAMS (1)

RECONFIGURABLE BEAMS



NORMAL SITUATION

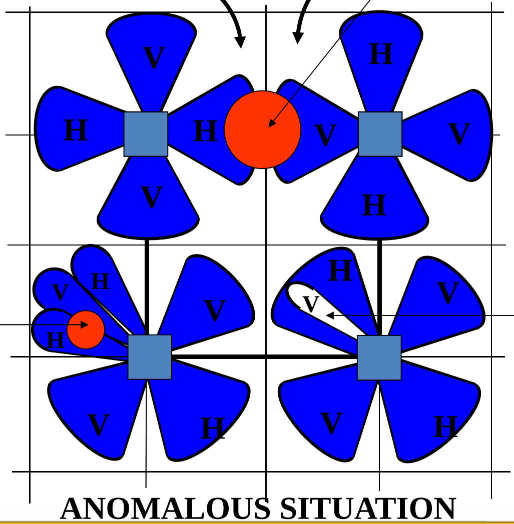
2.6. FUTURE TRENDS (3):

RECONFIGURABLE BEAMS (2)

RECONFIGURABLE BEAMS

BEAM STEERING

Interferences source



Polarization diversity

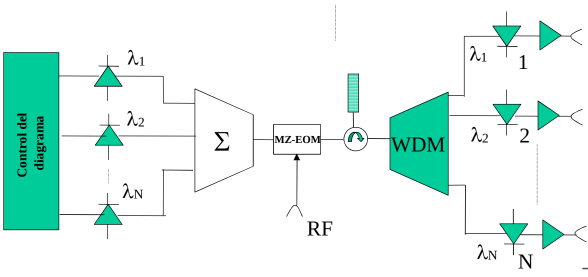
Dedicated beam

ANOMALOUS SITUATION

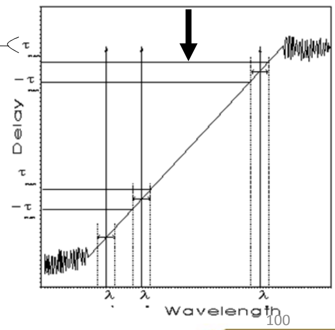
2.6. FUTURE TRENDS (4):

RECONFIGURABLE BEAMS (3)

OPTIC SHAPED OF BEAMS



Wide band diffraction network



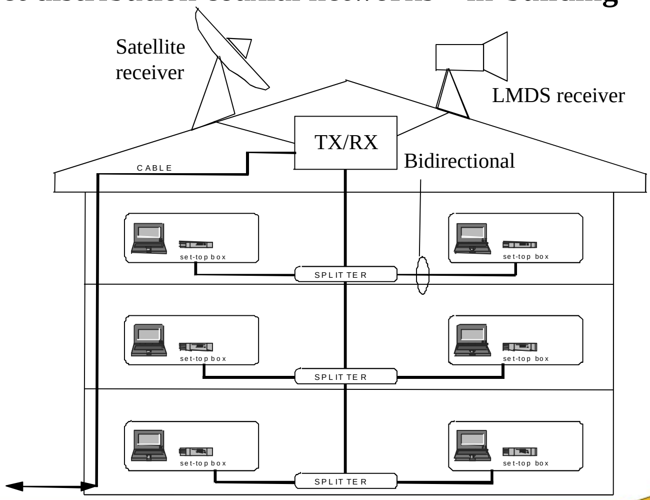
Variable delay according to wavelength

2.6. FUTURE TRENDS (5):

OPTICAL FIBER PASIVE DISTRIBUTION NETWORK

OPTICAL FIBER PASIVE DISTRIBUTION NETWORK

To set distribution coaxial networks "in-building"



2.6. FUTURE TRENDS (6):

OPTICAL FIBER PASIVE DISTRIBUTION NETWORK

WDM techniques, low cost return channel