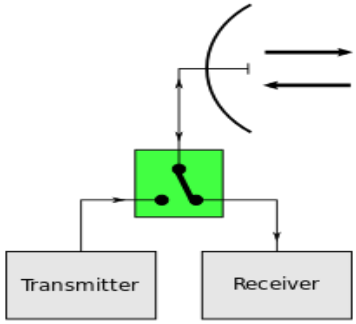
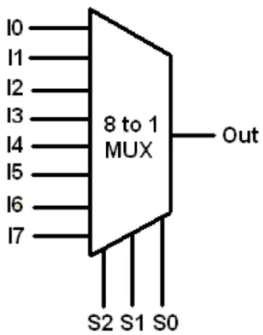
CHAPTER 1 :
Radio and Dimensioning Planning

1. Define the following terms:
   - Electromagnetic wave
   - Frequency carrier
   - Wavelength
   - Bandwidth
   - Power in dBW and in dBm
   - Communication range
   - Loss/Gain in dB
   - Antenna gain in dBi
   - Antenna tilt
   - Antenna aperture
   - EIRP = Equivalent Isotropic Radiated Power
   - Receiver sensitivity
   - Macro-cell / femtocell / micro-cell
   - Duplexer (Duplexer loss)



   - Multiplexer



2. The Erlang is a unit in telecommunications used to quantify the traffic in the network (in hour of calls). To find the traffic generated by the user, we need to estimate how long time the user occupies the radio resource during a unit of observation (usually one hour).

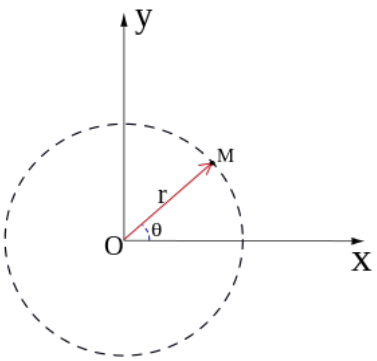
    a. We assume that the time unit of observation is 1 hour.
        i. During this hour, the user occupies the network radio resource for 18 minutes. Express the traffic in Erlang?
        ii. During this hour, the user occupies the network all the time. Express the traffic in Erlang?

3. Frequency properties: A list of frequencies is attributed to an operator. Indicate in each case, the suitable frequency to be used.
    a. The frequency with the smallest communication range:
        i. 1800 MHz (ii) 2600 MHz (iii) 3500 MHz
    b. The suitable frequency for rural zone deployment.
        i. 1800 MHz (ii) 2600 MHz (iii) 3500 MHz
    c. The most directive frequency :
        i. 1800 MHz (ii) 2600 MHz (iii) 3500 MHz
    d. The frequency with the smallest outdoor/indoor penetration loss :
        i. 900 MHz (ii) 1800 MHz (ii) 2100 MHz
    e. Which frequency do you recommend for femtocell use:
        i. 900 MHz (ii) 1800 MHz (ii) 2100 MHz

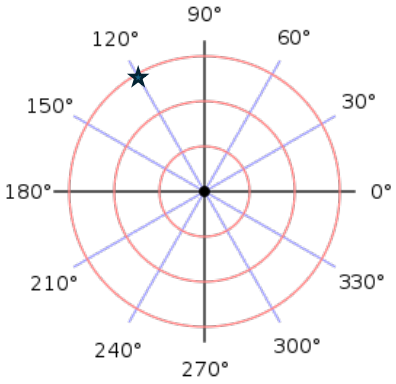
Exercise 1: Antenna Pattern

1.1 – Polar coordinats:

How to read polar coordinates?



Polar coordinate



Radius graduation: 1, 2, 3, 4, etc

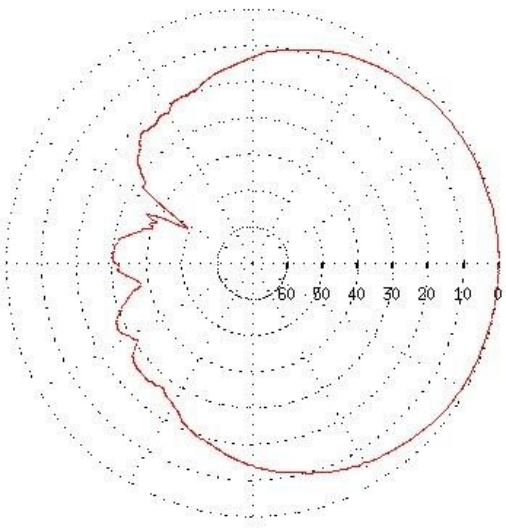
Find the polar coordinates of the star on the right figure. Deduce the cartesian coordinates.

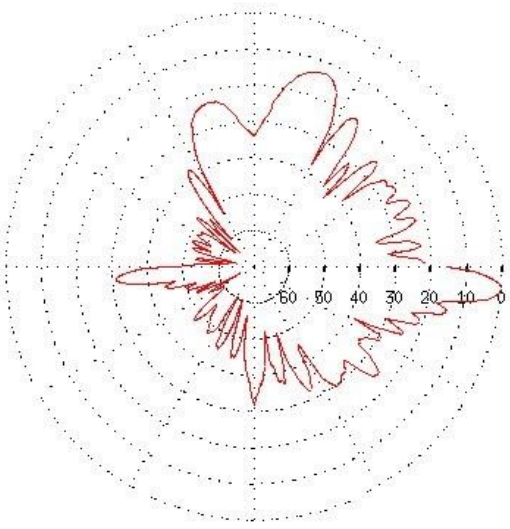
1.2 Antenna pattern:

We consider the following antenna:

antenna COMSAT (GAIN : 18,2 dB) :

Horizontal diagram Vertical diagram aperture: 85 ° aperture : 5 °
tilt : +5 °





(*graduation : **loss** in dB*)

1) What does the term aperture means: 85° (ou 5°) » ?
2) The transmitted power is 15W. Convert this power to dB and dBm.

We consider a pedestrian situated at an elevation: +5°and azimut : -60°.

3) Find the Equivalent Istostropic Radiated Power EIRP (in dB and in dBm)?

Exercise 2 : Link budget

The mobile sensitivity is: -100 dBm. The antenna gain is 1 dB, the power loss in cable is 1 dB. If the received power is (find the correct answer) :

a. - 98 dBm, then the reception is possible: yes no
b. -102 dBm then the reception is possible: yes no
c. -120 dB, then the reception is possible: yes no

The sensitivity of a network access point is: -110 dBm. Its antenna gain is 15 dB, the losses in the receiving cables are 10 dB. . If the received power is (find the correct answer) :

a. -110 dBm, then the reception is possible: yes no
b. -120 dB, then the reception is possible: yes no
c. -125 dBm, then the reception is possible: yes no
d. -130 dB, then the reception is possible: yes no

Exercise 3: Link budget - cell radius

In order to establish a link budget on the radio interface between a mobile and its access point to the network, the following hardware characteristics are considered:

Access point :

- Low noise amplifier : 2 dB
- antenna : 16 dBi
- cables & connectors : 3 dB
- Receiver diversity : 2 dB
- duplexer : 3dB
- Maximal transmitted power 50 W
- Sensitivity : -112 dBm

Mobiles :

- antenna : 0 dBi

- cables & connectors : 0 dB
- Power : 1 W
- sensitivity : -103 dBm

1) Explain what is the unit dBi.
2) Explain what the EIRP is.
3) What is reception diversity for access points, how is it characterized in the "landscape"? What would be the maximum gain introduced by this diversity?
4) Fill in the following table (especially the units) by justifying your calculations and deduce the transmission power (in Watts) of the access point to balance the link budget:

DOWNLINK			**UPLINK**		
Elements	unit	value	Elements	unit	value
Access Point			Access Point		
Mobile			Mobile		
Sensitivity :			Sensitivity		
EIRP			EIRP		
Downlink maximal Pathloss			Uplink maximal Pathloss :		

5) Use a propagation model of your choice and deduce the maximum distance Access point - mobile. We can consider the carrier frequency fp = 1800 MHz.

Exercise 4: Dimensioning cellular network :

We consider an area of 500 000 km² populated with 50 million inhabitants. It has 15 large cities far away from each other in which 3/5 of the population lives. The cities have an area of 100 km² each. A company receives a license to deploy and operate an FDD, F/TDMA type network in circuit mode. The administration allocates to it 70 pairs of frequency bands (duplex FDMA). Each frequency band is divided into 8 time slots (TDMA).
We consider:

- that the penetration rate is 2% in the cities and 0.1% in the rest of the territory.
- that it is necessary to have 1/8 of the radio resources used for signaling.
- that the correct operating threshold is for C / I = 9 dB. We take an extra margin of 8 dB to protect ourselves from mask and fading effects.
- that each subscriber generates 25 mE;
- Erlang B tables for a QoS of 2% (see next page for example, or on the Internet ...);
- that the coefficient of propagation is 3.3 in the cities and 3 elsewhere.

Rural zone only:

1) Calculate the size of the pattern.
2) Deduce the number of available pairs of frequencies per cell.
3) Calculate the total traffic in the zone.
4) Calculate the number of available traffic channels per cell.
5) Calculate the number of cells needed to handle the traffic of the whole area.
6) Deduce the area and dimensions of these cells.
7) Deduce that the limiting factor is the range and not the traffic (remember that the maximum distance access point to the network - mobile is of the order of 35 km)
8) Recalculate the number of cells to cover the territory, considering the maximum distance Network access point - mobile.
9) Deduce the traffic flow per cell and the number of frequency bands needed per cell.
10) Recalculate the size of the pattern that maximizes the quality of the network.

Urban zone only:

1) Calculate the size of the pattern.
2) Deduce the number of available pairs of frequencies per cell.
3) Calculate the total traffic to flow in the zone.
4) Deduce the traffic to flow in each city.
5) Calculate the number of available traffic channels per cell and deduce the traffic to be flown by each cell.
6) Calculate the number of cells needed in each city.
7) Calculate the area of each cell and deduce that the limiting factor is the traffic and not the range.

Erlang B Traffic Table

Maximum Offered Load Versus B and N
B is in %

N/B	0.01	0.05	0.1	0.5	1.0	2	5	10	15	20	30	40
1	.0001	.0005	.0010	.0050	.0101	.0204	.0526	.1111	.1765	.2500	.4286	.6667
2	.0142	.0321	.0458	.1054	.1526	.2235	.3813	.5954	.7962	1.000	1.449	2.000
3	.0868	.1517	.1938	.3490	.4555	.6022	.8994	1.271	1.603	1.930	2.633	3.480
4	.2347	.3624	.4393	.7012	.8694	1.092	1.525	2.045	2.501	2.945	3.891	5.021
5	.4520	.6486	.7621	1.132	1.361	1.657	2.219	2.881	3.454	4.010	5.189	6.596
6	.7282	.9957	1.146	1.622	1.909	2.276	2.960	3.758	4.445	5.109	6.514	8.191
7	1.054	1.392	1.579	2.158	2.501	2.935	3.738	4.666	5.461	6.230	7.856	9.800
8	1.422	1.830	2.051	2.730	3.128	3.627	4.543	5.597	6.498	7.369	9.213	11.42
9	1.826	2.302	2.558	3.333	3.783	4.345	5.370	6.546	7.551	8.522	10.58	13.05
10	2.260	2.803	3.092	3.961	4.461	5.084	6.216	7.511	8.616	9.685	11.95	14.68
11	2.722	3.329	3.651	4.610	5.160	5.842	7.076	8.487	9.691	10.86	13.33	16.31
12	3.207	3.878	4.231	5.279	5.876	6.615	7.950	9.474	10.78	12.04	14.72	17.95
13	3.713	4.447	4.831	5.964	6.607	7.402	8.835	10.47	11.87	13.22	16.11	19.60
14	4.239	5.032	5.446	6.663	7.352	8.200	9.730	11.47	12.97	14.41	17.50	21.24
15	4.781	5.634	6.077	7.376	8.108	9.010	10.63	12.48	14.07	15.61	18.90	22.89
16	5.339	6.250	6.722	8.100	8.875	9.828	11.54	13.50	15.18	16.81	20.30	24.54
17	5.911	6.878	7.378	8.834	9.652	10.66	12.46	14.52	16.29	18.01	21.70	26.19
18	6.496	7.519	8.046	9.578	10.44	11.49	13.39	15.55	17.41	19.22	23.10	27.84
19	7.093	8.170	8.724	10.33	11.23	12.33	14.32	16.58	18.53	20.42	24.51	29.50
20	7.701	8.831	9.412	11.09	12.03	13.18	15.25	17.61	19.65	21.64	25.92	31.15
21	8.319	9.501	10.11	11.86	12.84	14.04	16.19	18.65	20.77	22.85	27.33	32.81
22	8.946	10.18	10.81	12.64	13.65	14.90	17.13	19.69	21.90	24.06	28.74	34.46
23	9.583	10.87	11.52	13.42	14.47	15.76	18.08	20.74	23.03	25.28	30.15	36.12
24	10.23	11.56	12.24	14.20	15.30	16.63	19.03	21.78	24.16	26.50	31.56	37.78
25	10.88	12.26	12.97	15.00	16.13	17.51	19.99	22.83	25.30	27.72	32.97	39.44
26	11.54	12.97	13.70	15.80	16.96	18.38	20.94	23.89	26.43	28.94	34.39	41.10
27	12.21	13.69	14.44	16.60	17.80	19.27	21.90	24.94	27.57	30.16	35.80	42.76
28	12.88	14.41	15.18	17.41	18.64	20.15	22.87	26.00	28.71	31.39	37.21	44.41
29	13.56	15.13	15.93	18.22	19.49	21.04	23.83	27.05	29.85	32.61	38.63	46.07
30	14.25	15.86	16.68	19.03	20.34	21.93	24.80	28.11	31.00	33.84	40.05	47.74
31	14.94	16.60	17.44	19.85	21.19	22.83	25.77	29.17	32.14	35.07	41.46	49.40
32	15.63	17.34	18.21	20.68	22.05	23.73	26.75	30.24	33.28	36.30	42.88	51.06
33	16.34	18.09	18.97	21.51	22.91	24.63	27.72	31.30	34.43	37.52	44.30	52.72
34	17.04	18.84	19.74	22.34	23.77	25.53	28.70	32.37	35.58	38.75	45.72	54.38
35	17.75	19.59	20.52	23.17	24.64	26.44	29.68	33.43	36.72	39.99	47.14	56.04
36	18.47	20.35	21.30	24.01	25.51	27.34	30.66	34.50	37.87	41.22	48.56	57.70
37	19.19	21.11	22.08	24.85	26.38	28.25	31.64	35.57	39.02	42.45	49.98	59.37
38	19.91	21.87	22.86	25.69	27.25	29.17	32.62	36.64	40.17	43.68	51.40	61.03
39	20.64	22.64	23.65	26.53	28.13	30.08	33.61	37.72	41.32	44.91	52.82	62.69
40	21.37	23.41	24.44	27.38	29.01	31.00	34.60	38.79	42.48	46.15	54.24	64.35
41	22.11	24.19	25.24	28.23	29.89	31.92	35.58	39.86	43.63	47.38	55.66	66.02
42	22.85	24.97	26.04	29.09	30.77	32.84	36.57	40.94	44.78	48.62	57.08	67.68
43	23.59	25.75	26.84	29.94	31.66	33.76	37.57	42.01	45.94	49.85	58.50	69.34

B = Blockage probability – N = number of resources to handle the traffic