Selectivity

Although no receiver specification is unimportant, if one had to choose between sensitivity and selectivity, the proper choice would be to take selectivity over sensitivity.

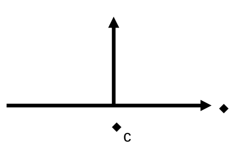
Selectivity

- Selectivity is the measure of a receiver's ability to reject interfering signals to the desired signal.
- An non-modulated radio carrier theoretically has an infinitely small bandwidth[1].
- As soon as the carrier is modulated to carry information the bandwidth is spread.
- The conclusion is that all information transportation occupies bandwidth.

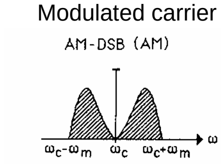
[1] All real non-modulated carriers have a very narrow, but not zero, bandwidth because they are modulated by noise.

Selectivity

Carrier



Modulated carrier



Selectivity

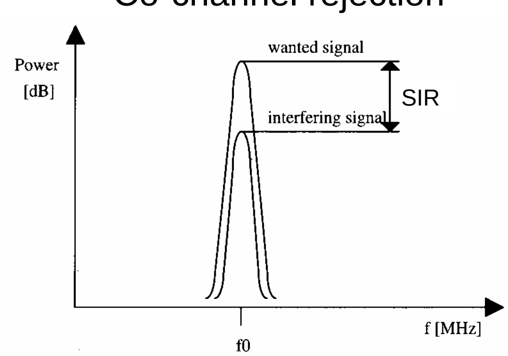
- An implication of the fact that radio signals have bandwidth is that the receiver must have sufficient bandwidth to recover all of the signal.
- On the other hand allowing too much bandwidth increases the noise picked up by the receiver and thereby deteriorates the SNR.
- The selectivity is also important in order to keep out of band signals from afflicting the receiver.

Co-channel rejection

- Co-channel rejection is an indication of the receiver's robustness against the reception of a signal on the same channel.
- The co-channel interference is the major limiting factor in cellular systems.
- We express this robustness against interfering signals as the **signal to interference ratio** (SIR).

$$SIR = \frac{S}{I}$$

Co-channel rejection



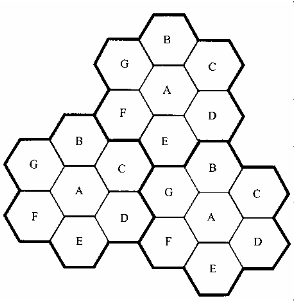
Co-channel rejection

- In a cellular system cannot co-channel interference be combated by simply increasing the carrier power of a transmitter, i.e., increasing the SNR.
- This is because an increase in carrier transmit power increase the interference to neighbor **co-channel** cells.
- To reduce co-channel interference, co-channel cells must be **physically separated** by a minimum distance to provide sufficient isolation due to path loss

Co-channel in cellular system

- A cellular system is based on that each cell is allocated a number of frequency bands.
- Adjacent cells are assigned different frequencies to avoid interference.
- However cells at sufficient distance from each other reuse the same frequency band.

Co-channel interference in cellular system



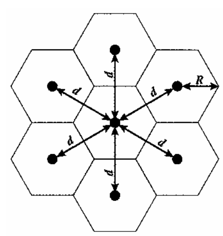
When considering geometric shapes of cells, which cover an entire region without overlap and with equal area, there are three possible choices; an equilateral triangle, a square and hexagons.

The hexagon's shape is chosen since it has the largest cover area for a given distance between its center and its farthest perimeter points.

Co-channel interference in cellular system

- When the size of each cell is approximately the same, and the base stations transmit the same power, the co-channel interference ratio is dependent of the **transmitted power** and a function of **the radius of the cell** (*R*) and the **distance between centers of nearest co-channel cells** (*D*).
- By increasing the ratio of D/R, the spatial separation between cells relative to the cover area distance of a cell is increased.
- Thus, the interference is reduced, from improved isolation of RF energy from co-channel cells.

Co-channel interference in cellular system



$$Q = \frac{D}{R} = \sqrt{3N}$$

D = minimum distance between centers of cells that use the same band of frequencies (co-channel cells).

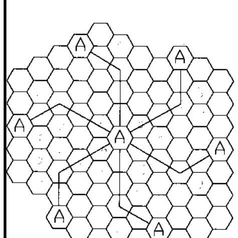
R = Radius of a cell

d = distance between centers of adjacent cells (*d*=⌧3*R*).

N = Number of cells in a repetitious pattern (each cell in the pattern uses a unique band of frequencies), termed **reuse factor**.

Q =Co-channel reuse ratio.

Co-channel interference in cellular S.



Due to the fact that the hexagonal geometry has six equidistant neighbors and that the lines joining the centers of any cell and each of its neighbors are separated by multiples of 60 degrees, there are only certain cluster sizes and layouts that are possible.

In order to tessellate without gaps between adjacent cells the geometry of hexagons is such that the number of cells per **cluster**, N, can only have values which satisfy:

$N = i^2 + ij + j^2$ where i, j = 0,1,2,3…..

Possible values for N is: 1,3,4,7,9,12,13,16

Where *i* and *j* are non negative integers. To find the nearest co-channel neighbor of a particular cell, one must do the following:

1. Move *i* cells along any chain of hexagon.
2. Then turn 60 degrees counterclockwise and move *j* cells.

Co-channel interference in cellular system

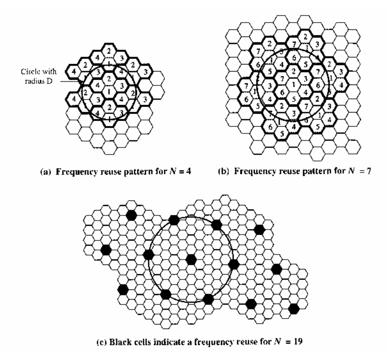
The SIR in a cellular system can be calculated according to:

$$\frac{S}{I} = \frac{S}{\sum_{i=1}^{i_0} I_i}$$

And a good estimate of the SIR is calculated by simply using the distance:

$$\frac{S}{I} = \frac{R^{-n}}{\sum_{i=1}^{i_0} (D_i)^{-n}} \Rightarrow \frac{(D/R)^n}{i_0} \Rightarrow \frac{\left(\sqrt{3N}\right)^n}{i_0}$$

Co-channel interference in cellular system



(a) Frequency reuse pattern for $N = 4$

(b) Frequency reuse pattern for $N = 7$

(c) Black cells indicate a frequency reuse for $N = 19$

Adjacent channel interference

- Interference resulting from signals which are adjacent in frequency to the desired signal is called adjacent channel interference.
- Adjacent channel interference results from imperfect receiver filters which allow nearby frequencies to leak into the pass band.
- The problem can be particular serious if an adjacent channel user is transmitting in very close range to the subscriber's receiver, while the receiver attempts to receive a base station on the desired channel.
- This is referred to as near-far effect, where a nearby transmitter captures the receiver of the subscriber.

Adjacent channel interference

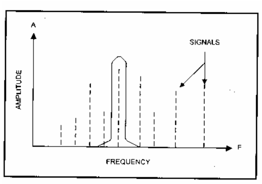
TX1 transmit to RX_1 at frequency f_1.

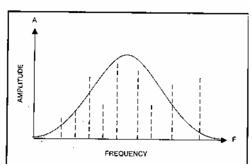
At a adjacent frequency f_2 TX_2 is transmitting simultaneously.

Even if the signal from TX_2 is on adjacent channel the signal is strong enough to interfere with the desired signal from TX_1.

Adjacent channel interference

Adjacent interference is removed with careful filtering at the receiver.





Adjacent channel interference

The interference performance on Co-channel and adjacent 1 MHz and 2 MHz are measured with the wanted signal 10 dB over the reference sensitivity level. On all other frequencies the wanted signal shall be 3 dB over the reference sensitivity level. The interfering signal shall be Bluetooth modulated (see section 4.8 on page 27). The BER shall be ≤ 0.1 %. The signal to interference ratio shall be:

Requirement	Ratio
Co-Channel interference, $C/I_{co\text{-}channel}$	11 dB[1)]
Adjacent (1 MHz) interference, C/I_{1MHz}	0 dB[1]
Adjacent (2 MHz) interference, C/I_{2MHz}	-30 dB
Adjacent (≥3 MHz) interference, $C/I_{\geq 3MHz}$	-40 dB
Image frequency Interference[2) 3)], C/I_{Image}	-9 dB[1]
Adjacent (1 MHz) interference to in-band image frequency, $C/I_{Image\pm 1MHz}$	-20 dB[1]

Table 4.1: Interference performance