Mobile Communication Systems

Part IV - Interference

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Content

- Introduction
- Types of interference
- How to combat interference
- Signal-to-interference ratio

Interference

- Interference is the major limiting factor in the performance of cellular radio systems. Sources of interference include:
  - another mobile in the same cell
  - a call in progress in the neighbouring cell
  - other BS s operating in the same frequency band
  - any non-cellular system which inadvertently leaks energy into the cellular frequency band.

Interference effects:

• on voice channel causes ***crosstalk***

• on control channels it leads missed and blocked calls due to errors in the digital signalling.

Interference - *contd.*

- Interference is more severe in the urban areas, due to
  - the greater RF noise floor
  - large number of BSs and mobiles

Interference has been recognised as a major bottleneck in increasing capacity and is often responsible for dropped calls

Types of Interference

- Co-channel
- Adjacent channel
- Power level
- Multipath

Co-channel Interference (CCI)

- Is due to frequency reuse in a given coverage area.
- Unlike thermal noise, which can be overcome by increasing the signal-to-noise ratio, CCI can not be reduced by simply increasing the signal (carrier) power at the transmitter.

  This is because an increase in carrier transmit power increases the interference to neighbouring co-channel cells.
- To reduce CCI, co-channel cells needs to be physically separated by a minimum distance to provide sufficient isolation due to propagation.

Co-channel Interference - *contd.*

- The signal-to-interference ratio (*SIR*) for a mobile receiver monitoring a forward channel is given as:

$$SIR = \frac{S}{\sum_{i=1}^{i_o} I_i}$$

$SIR \sim 17$ -19 dB

where

i_o = No. of co-channel interfering cells

S = Signal power from a desired BS

I_i = interference power caused by the i^{th} interfering co-channel cell BS.

Co-channel Interference - *contd.*

- Average received power P_r at a distance d from the transmitting antenna is:

$$P_r = P_0\left(\frac{d}{d_0}\right)^{-n}$$

Or in dB

$$P_r(dBm) = P_0(dBm) - 10n\text{Log}\left(\frac{d}{d_0}\right)$$

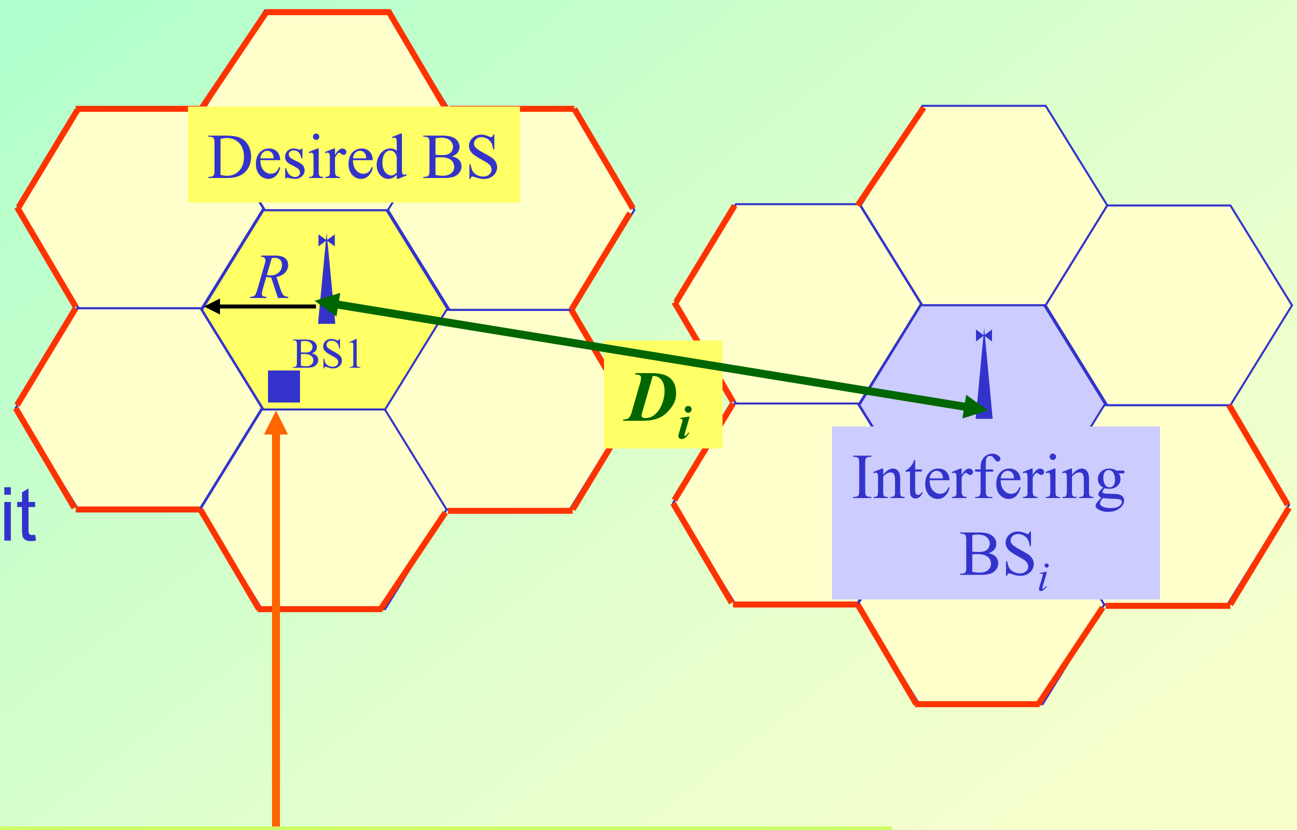
where

P_0 = Power received at a close-in reference point in the far field region of the antenna at a small distance d_0 from the Tx antenna.

n = Path lose exponent. 2< n <4 for urban cellular.

Co-channel Interference - *contd.*

- Lets consider the forward link where :



■ Mobile unit

$$S \,\alpha\, R^{-n} \qquad \text{And} \qquad I_i \,\alpha\, (D_i)^{-n}$$

Co-channel Interference - *contd.*

- Assuming
  - transmitted power of each BS is equal
  - *n* is the same throughout the coverage area,

$$SIR = \frac{R^{-n}}{\sum_{i=1}^{i_0} (D_i)^{-n}}$$

- If all the interfering BSs are equidistant from the desired BS
- If this distance is equal to the distance *D* between the cells
- Since $Q = D/R$

$$SIR = \frac{(D/R)^n}{i_0}$$

$$= \frac{\left(\sqrt{3N}\right)^n}{i_0}$$

Co-channel Interference - Example

- *For the USA AMPS cellular system which uses FM and 30 kHz channels, a 7-cell cluster might be used there could be up to 6 immediate interference, Assuming the fourth power propagation law, an approximate value of the SNI would be:*

Solution:

$$SIR = \frac{S}{\sum 6I's} = \frac{R^{-4}}{6D^{-4}}$$

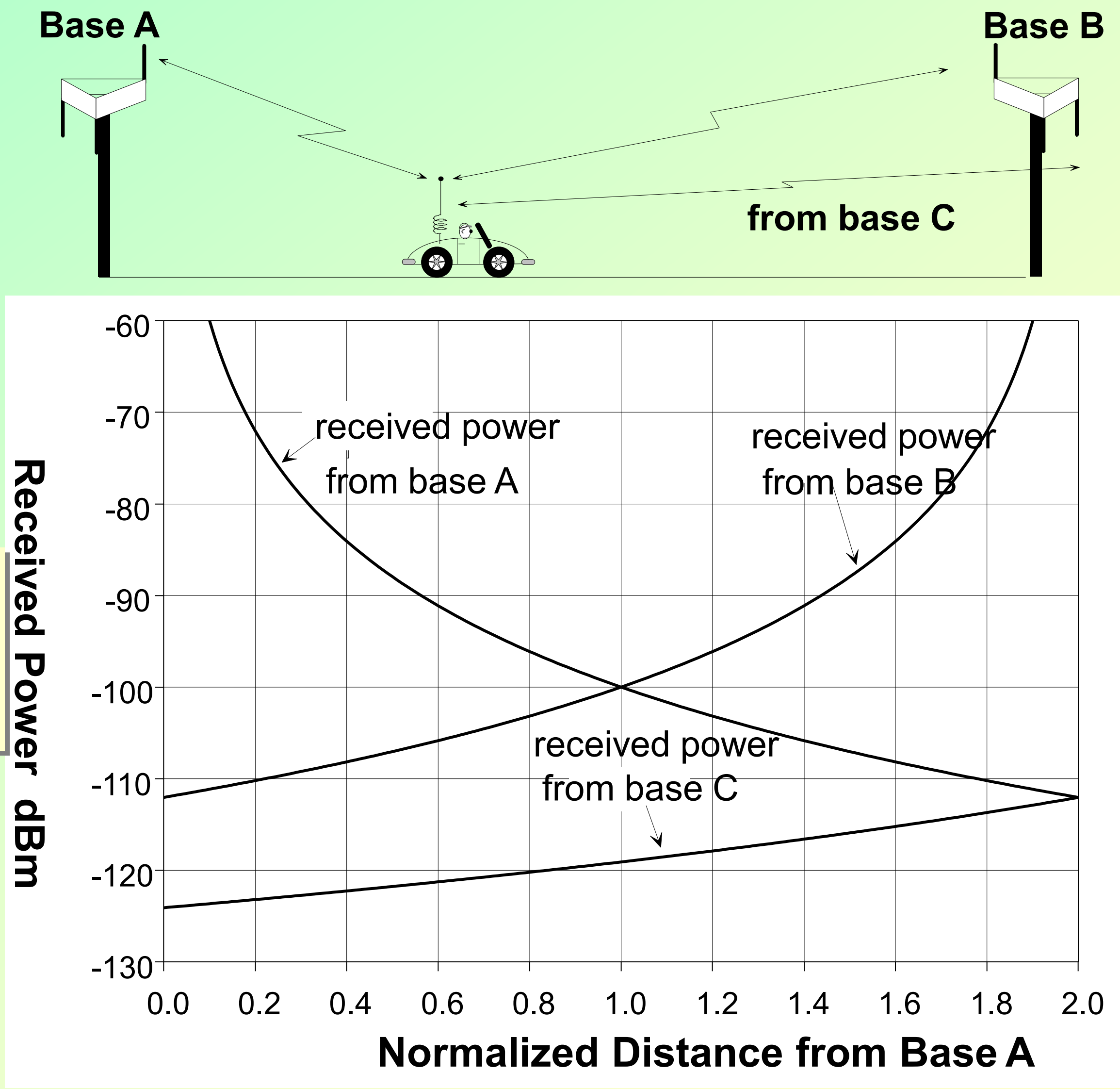
since $D/R = (3N)^{1/2}$, then
$SIR = 1.5\,N^2 = 1.5\,(7)^2 = 74$
in dB $SIR = 10 \log (74) = 19$ dB.

Compared with 13 dB for GSM

Co-channel Interference

If stations A and B are using the same channel, the signal power from B is co-channel interference:

$$SIR(d_A, D) = P_A(d_A) - P_B(D - d_A)$$
$$= -\log_{10}[(D/d_A) - 1] \quad dB$$



Performance

- Since $\left(\frac{S}{I}\right)_{min} \le \frac{1}{i_0}\left(\frac{R}{D_{cc}}\right)^{-n}$ and $Q = \left[i_0\left(\frac{S}{I}\right)_{min}\right]^{1/n}$

And $Q = \sqrt{(N)}$

- The channel capacity/cell $C = \frac{B_T}{B_{ch}N} = \frac{B_T}{B_{ch}Q^2/3}$

$$C = \frac{B_T}{B_{ch}\frac{1}{3}\left[i_0\left(\frac{S}{I}\right)_{min}\right]^{2/n}} = \frac{B_T}{B_{ch}\left[\frac{i_0}{3^{n/2}}\left(\frac{S}{I}\right)_{min}\right]^{2/n}}$$

B_T: Total allocated bandwidth
B_{ch}: Channel bandwidth
n: Path loss exponent
$S/I)_{min}$: Minimum S/I

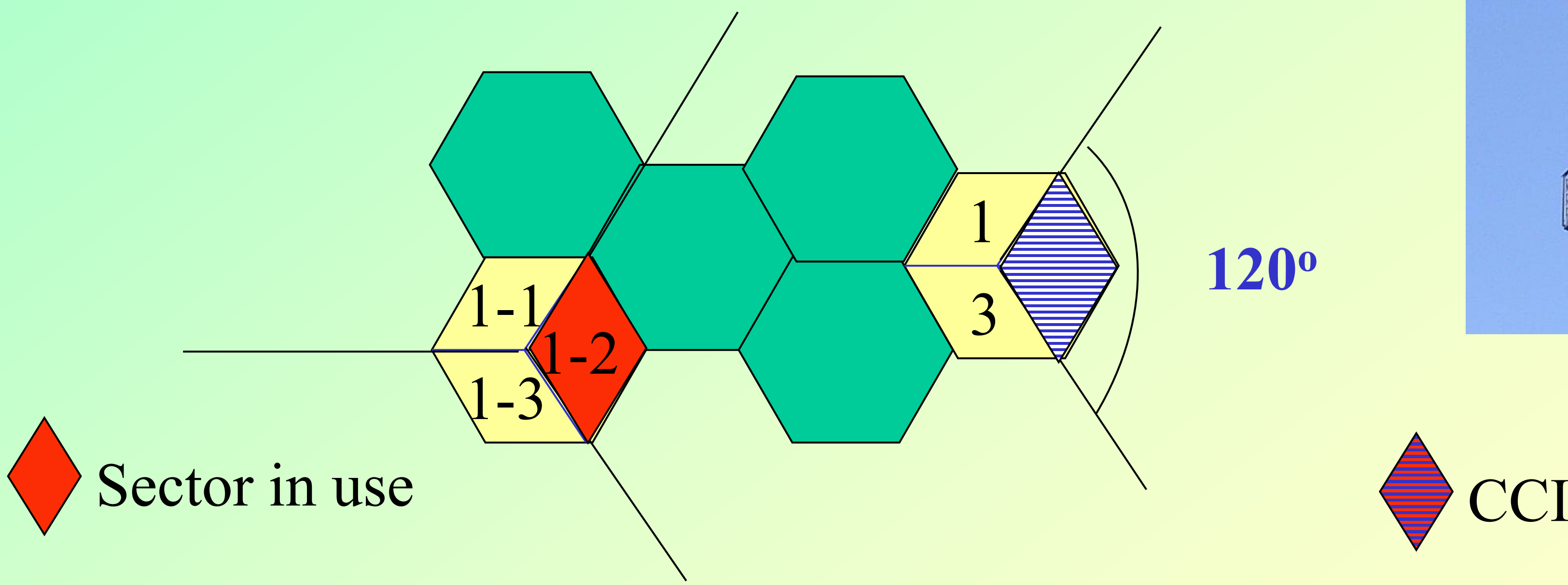
Digital System

- In digital systems we have $$\frac{S}{I} = \frac{E_b R_b}{I}$$

  where E_b is the energy per bit and R_b is the bit rate

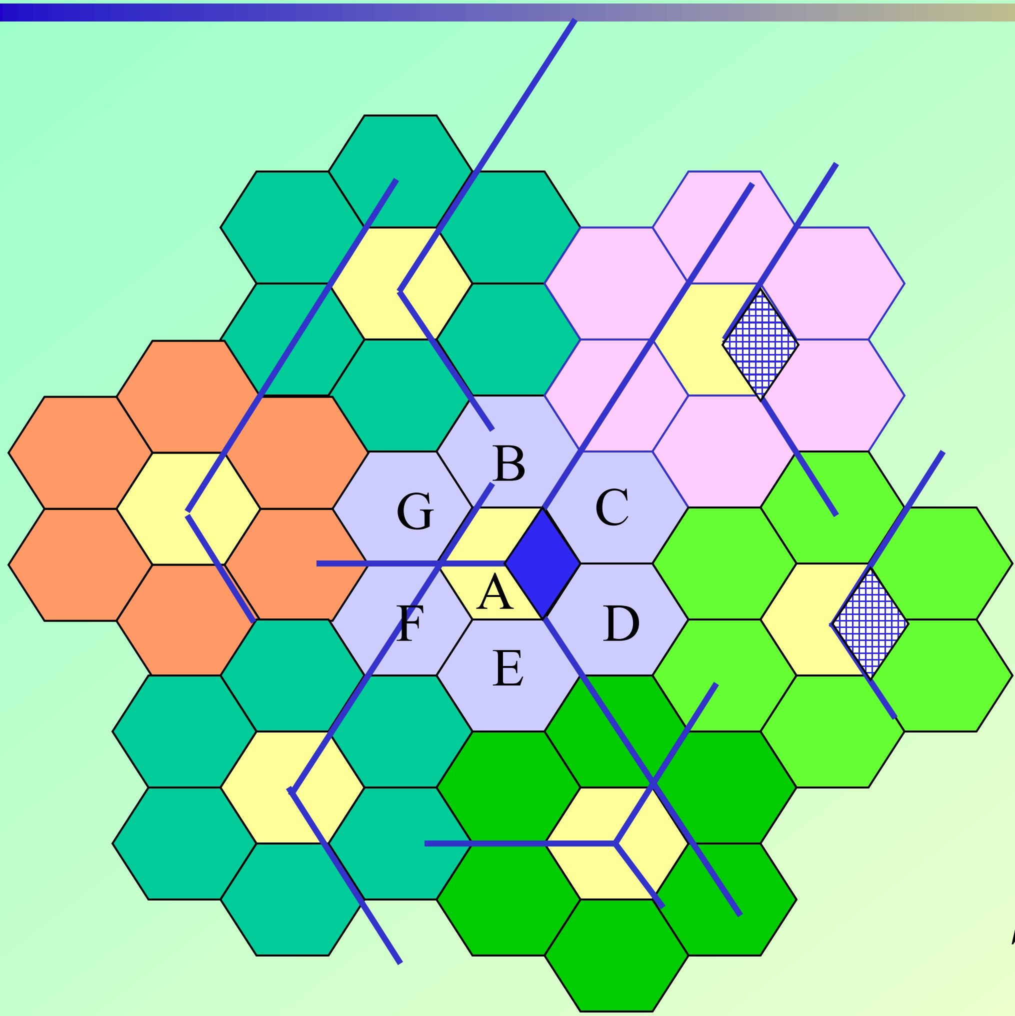
How to Reduce CCI – Sectorisation (Directional Antenna)

- Use of a directional antenna instead of omnidirectional antenna: 120º or 60º sector antenna
- The frequency band is further subdivided (denoted 1-1, 1-2, 1-3, etc.). This does not use up frequencies faster (same number of channels/cell)



Cell with 3 sectors having their own frequencies and antennas

How to Reduce CCI – Sectorisation



For a 7-cell cluster, the MU will receive signals from only 2 other cluster (instead of 6 in an omnidirectional antenna)

For worst case, when mobile is at the edge of the cell

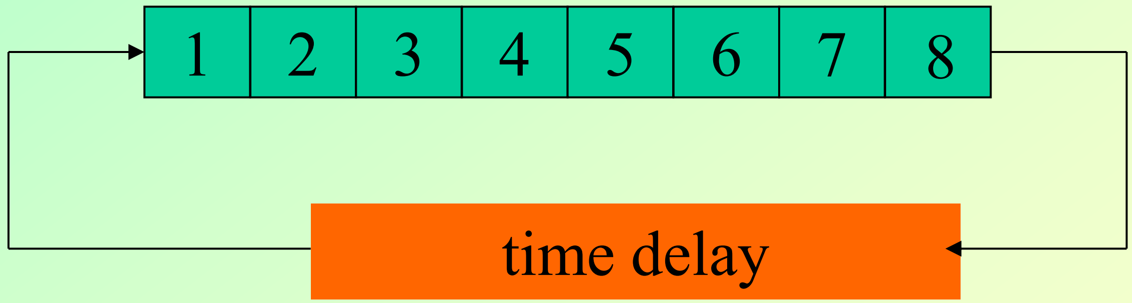
$$SIR = \frac{R^{-n}}{D^{-n} + (D + 0.7R)^{-n}}$$

Desired channel

Interfering co-channel cells @ *D* distance

How to Reduce CCI – *contd.*

- Sequential Transmitter
  - Only one transmitter is being used while all the surrounding transmitters are switched off (i.e transmitters are turned on in turn)



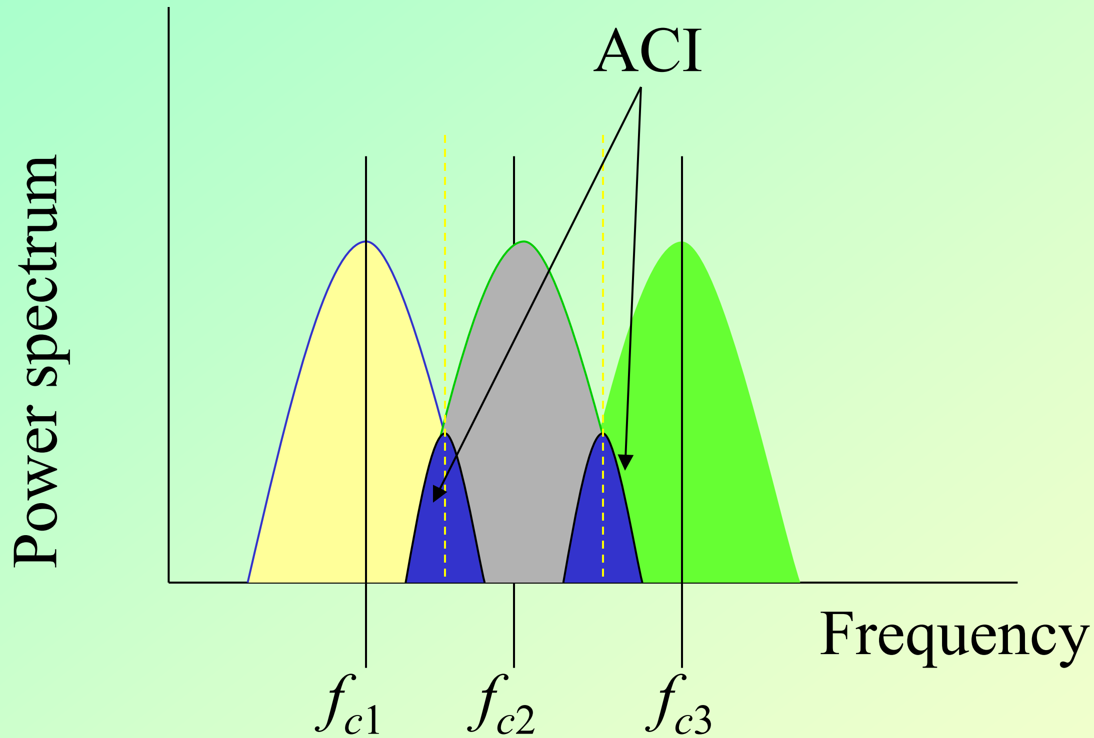
Adjacent Channel Interference (ACI)

- Results from signals which are adjacent in frequency to the desired signal due to imperfect receiver filters.
- It can be serious if an adjacent channel user is transmitting in very close range to a mobile unit. This is refereed to as the NEAR-FAR EFFECT (NFF)
- NFF also occurs when a mobile close to a BS transmits on a channel close to one being used by a weak mobile.

Can be minimised by:

- careful filtering
- careful channel assignments:
  – careful frequency allocation
  – sequential assigning successive channels in the frequency band to different cells.

Adjacent Channel Interference - *contd.*



Out-of-Cell Interference

Q - If a single high-power source does not provide sufficient capacity and cannot combat the shadowing effect, could multiple high-power sources provide a solution?

i.e.,

- For indoor deployment, can one simply install a large number of picocell eNodeBs into the indoor area and reduce the inter-cell distance, so the picocells effectively act like femtocells?
- A similar question applies for outdoor deployment: can one simply install a large number of macrocell eNBs and reduce the inter-cell distance, so these macrocells can act like microcells?

Ans.

In the early days of wireless communication, with a very limited base station, many networks were indeed deployed this way.

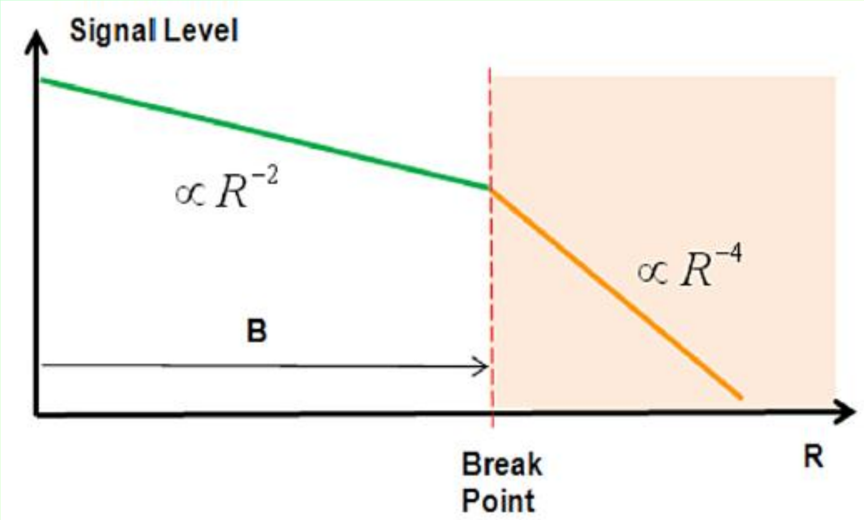
However, there are several undesirable effects if high-power base stations are deployed too close to each other.

Out-of-Cell Interference

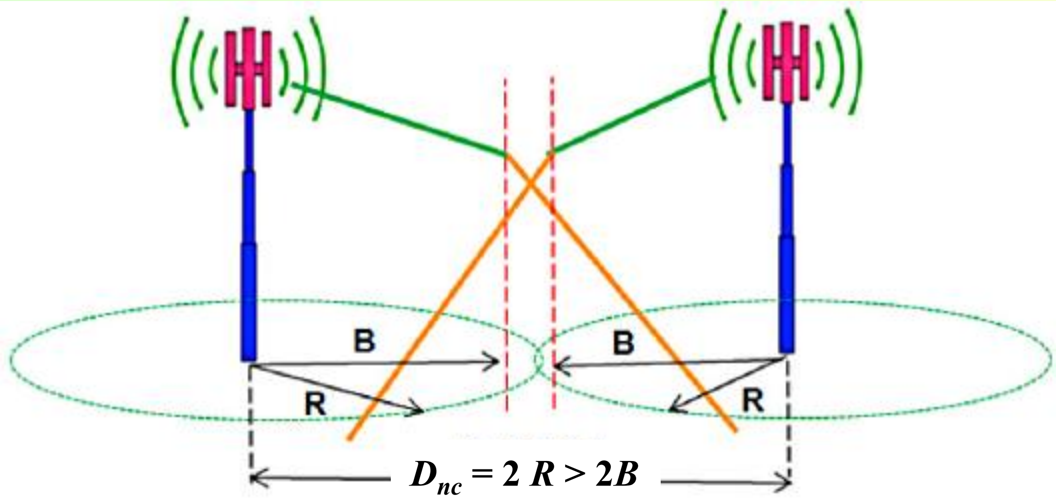
It is desirable for the inter-cell distance D_{nc} to be slightly more than twice the value of B,
$D_{nc} > 2^*B$

So that the in-cell signal level will have a slower attenuation ($\propto R^{-2}$

but out-of-cell interference I_{oc} will have a faster attenuation ($\propto R^{-4}$). Since B is a function of the base station antenna height h_{bs}, for a certain antenna height h_{bs}, only properly spaced base stations can maximize the S/I.

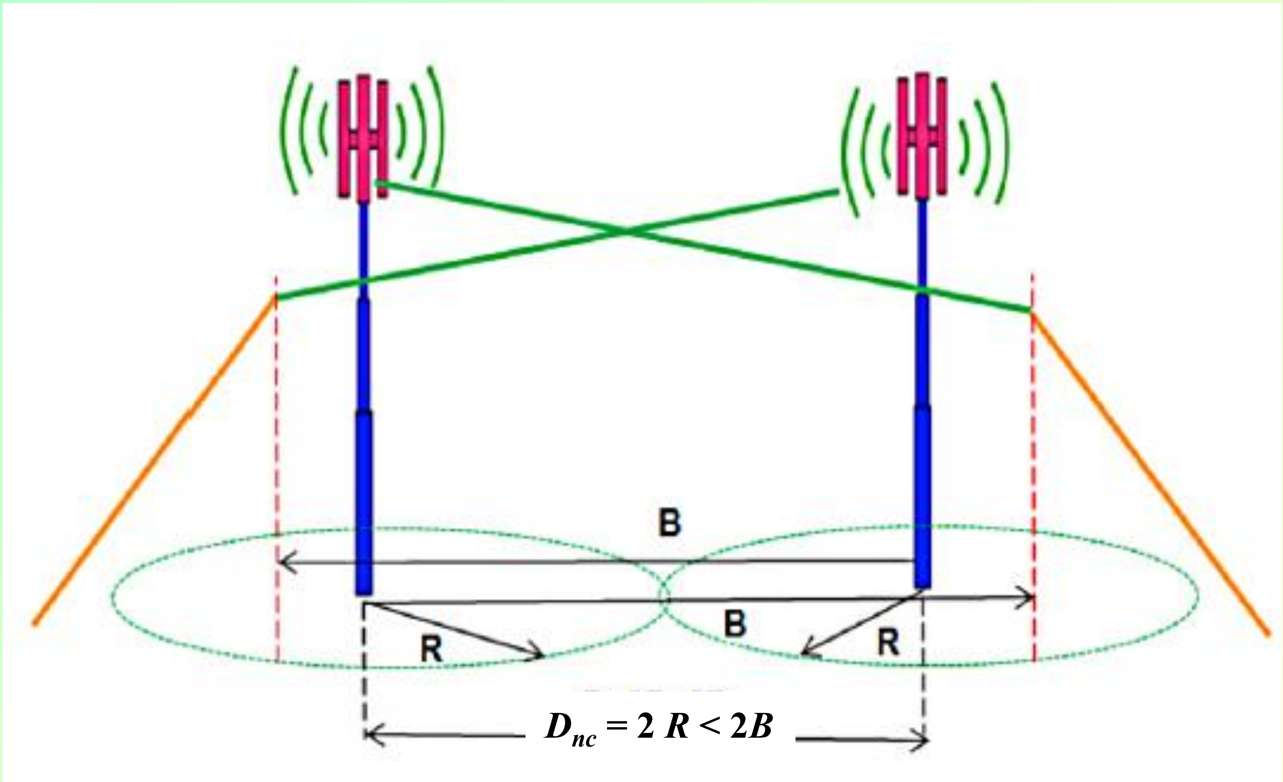


Two-slope RF propagation model



Out-of-Cell Interference

If the neighbouring base stations are installed too close to each other so that the inter-cell distance D_{nc} < $2B$, then I_{oc} will not attenuate fast enough, thus the overall *S/I* degrades.

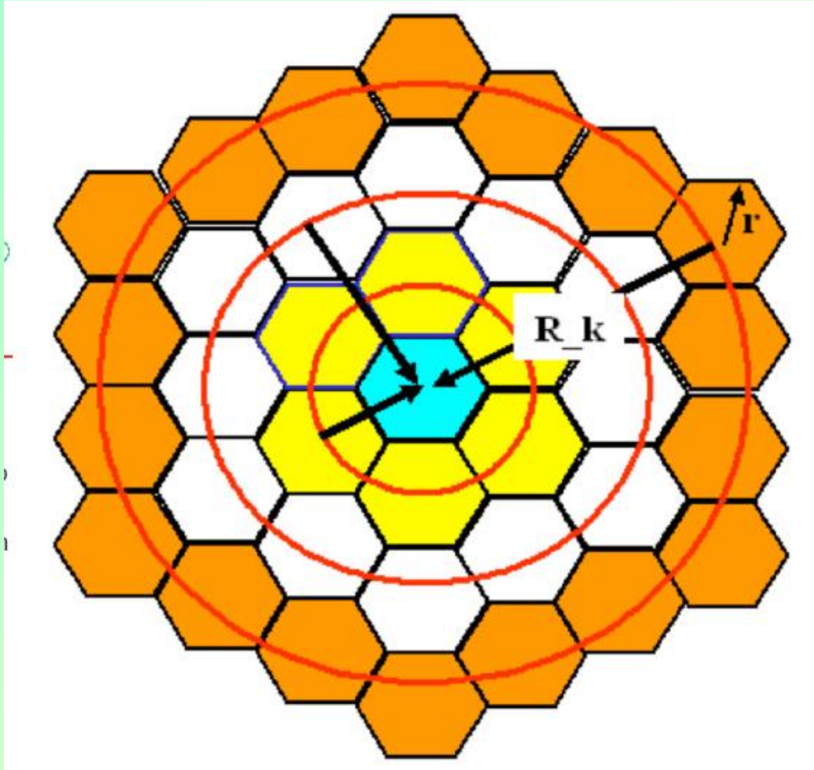


Out-of-Cell Interference

Total out-of-cell interference

$$I_{oc-total} = \sum_i^n I_{i-1st} + \sum_j^m I_{j-2nd} + \sum_k^o I_{k-kt} +$$

1st tier neighbours | 2nd tier neighbours | kth tier neighbours

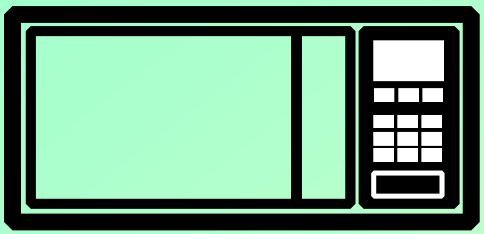


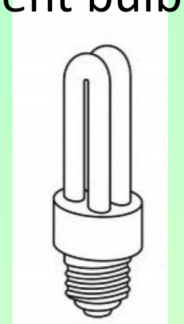
Total out-of-cell interference to one cell (blue) is the sum of interference contributed from all neighbours

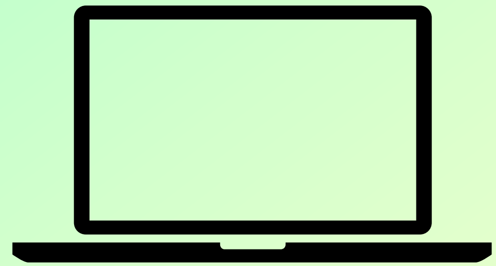
Interference – Due to non-communicating source emissions …

Non-communicating devices

Microwave ovens Fluorescent bulbs



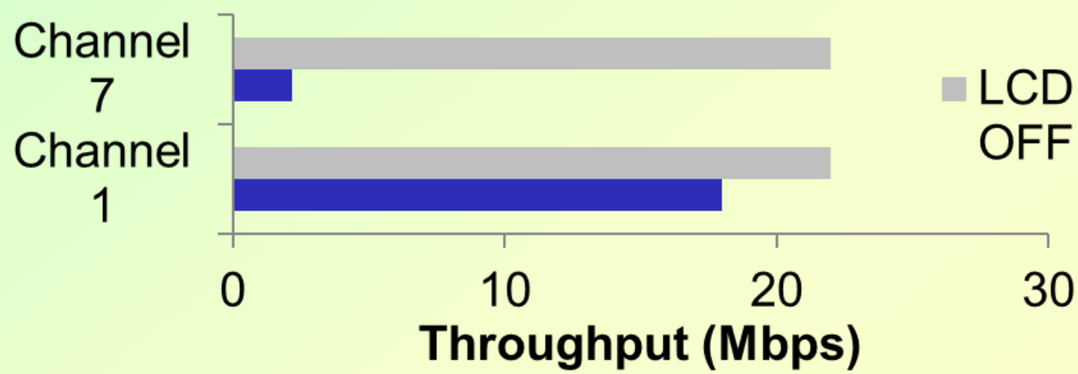




Computational Platform

Clocks, amplifiers, busses

Impact of platform interference from a laptop LCD on wireless throughput (IEEE 802.11g) [Slattery06]



Summary

- Interference (CCI + ACI)
- How to Combat Interference
- Signal-to-Noise Ratio

Next Lecture

Traffic Engineering