Wireless Channel & Interference

Interference

whats wireless all about ? interference

- Interference in digital baseband design
- Intentional interference (in the design) – NOMA
- Pulse shape related-partial overlapping
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- RF interference (intermodulation products, adjacent channel re-growth, Frequency offset (ICI), timing jitter (ISI), clock error (ISI, ICI), IQ interference. Interbeam interference (antenna)
- Self and other user interference
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- Channel caused interference
- Dispersion in time, frequency, space
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- Network design related interference (intercell interference)
- Co-channel, inter-cell interference, cell edge interference and problem
- Inter-network interference
- Co-existence related interference (policy based interference, the spectrum allocation)
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- Multiple accessing related interference (intercode interference, code domain power, Rho)
- Code leakage (CDMA)
- Random access related interference (collision)
- Adjacent channel interference
- Inter-numerology interference
- Narrowband interference
- Impulsive interference
-

Interference and sinr and adaptive modulation, data rate, capacity

- Jamming
- Spoofing
-
- Self interference (ISI, ICI)
- Multi-user interference (CCI, ACI)

- Full duplex interference

- Interference alignment
- Multi-user communication
- Interference coordination
- Interference cancellation
- Interference averaging

- Interference awareness
- Interference measurements

- frequency offset and ICI
  sampling timing offset and ISI
- frequency ofset estimation and compansation

Channel

medium vs effective channel. we'll be considering the former.

- Importance of channel estimation, effect of fading, and channel compensation
- channel estimation, phase correction, amplitude correction, due to the channel

- Channel and modulation type
  Pulse shape and channel
  RF front end and channel

- How to generate the channel, how to obtain artificial channel. Emulator, chambers.
  Reverberation chamber versus anechoic chamber.
  Indoor channel properties relation to bandwidth.
  Indoor and outdoor channel differences.
  Stochastic nature of the channel, and generation wide variety of channel scenarios to be able to test the radios and networks.

  LOS versus NLOS
  Doppler spectrum and mobility and how to obtain. Our papers.
  Delay spread and multipath generations. Our papers and approaches.
  Compare the digital emulator with our solutions.

  Discuss the effect of the channel to different signals.
- Bandwidth, waveform, and other relations with channel.

  How to visualize the effect of the channel with measurement tools, eye diagram, constellation diagram, spectrum plot, spectrogram.

  Channel estimation versus channel sounding.
  VNA versus sounding based channel characterization.
- REM and channel relation, obtaining REM from channel

- Channel coding, interleaving (time&frequency), equalization, diversity
- Channel modeling and channel sounding and channel estimation
- Least square channel estimation
- Time domain versus frequency domain channel estimation
- LOS versus NLOS estimation
- Blockage estimation
- Spreading estimation, selectivity estimation
- Sparsity estimation
- RSSI estimation
- REM

- Model based channel estimation versus machine learning based channel estimation
- Model estimation
- Channel estimation versus channel models

- Channel based authentication
- Channel based PHY security

Observing the channel in the lab

- Reverberation channel
- Anechoic channel
- Doppler and mobility (rotating fan)
- Delay spread and saw filters
- BW and resolvability
- Blocking the signal
- RIS (LIS) ??? Absorbers in reverberation
- Directional antennas (120 degree) – check with Gokhan hoca
- Medipol 15 degree horn antenna (2 of them) – angular spread, blockage
- Can we think of something in LIS

- 2 generators, one is creating different types of interference (BW, power, distance, co-channel or adjacent)
- Jamming (try to jam the communication)
- Narrowband interference (impulsive in freq)
- Impulsive interference
- Relation of waveform and interference
- Wifi signal operating and try to interfere with it. Take a look at the spectrum analyzer
- Bluetooth test. Spectrogram and see the hopping sequence is changing before and after the jamming.
- Can we do full duplex

Waveform Alignment

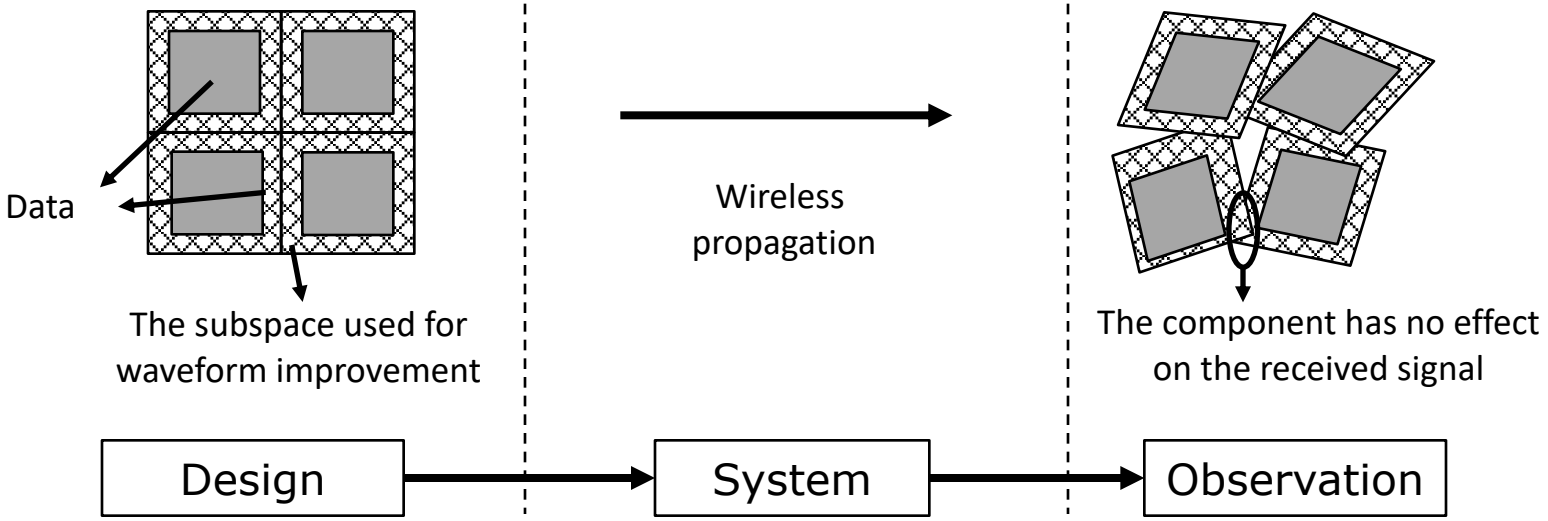
Transmitted signal occupies larger space than the actual information signal.

E.g.: Guard time, guard band, redundancy, dimension reduction, MIMO, etc..

System creates distortion on the waveform:

E.g.: warping effect of multipath channel in the signal-space

Receiver captures the information signal and discards the redundant parts in the signal.



Waveform Alignment Option 1: Optimizing waveform in multiple sense via additional component that is aligned with the redundant space at the receiver

Waveform and Channel Relation- Doppler Spread

- High speed applications leads mobility, creating Doppler spread (when there is multipath and if the multipath is coming from different angles).
  - Hence, number of multipath components, the angle of arrival of multipath components, along with mobility cause Doppler spread
  - Doppler spread cause ICI and ACI
  - To avoid ICI and ICI, the waveform should be localized in frequency, perhaps with some guards
  - Localization in Frequency contradicts with localization in time
  - Overlapped carriers does not get along with ICI, causing loss of orthogonality
- High speed applications cause time variation of channel
  - Large symbol duration is not desired

Waveform and Channel Relation- delay Spread

- Wideband transmission for a given environment are more frequency selective (more time dispersive)
- Longer range multipath communication for a given bandwidth leads more delay spread
- Environment, and variations multipath delays cause larger spreading. Application and operating environment impacts delay spread
- Delay spread causes ISI, IBI

- A pulse that is not localized in time can also cause ISI, IBI

Waveform and Channel Relation- Multipath

- Multipath delay differences depend on operating environment. Delay difference cause time spreading
- Multipath angular spreading depends on environment and antenna beam. Angular variation cause Doppler spread when there is mobility
- Multipath richness effect small scale fading along with the resolvability of these multipath components. Multipath richness depends on the environment. Multipath fading is related to waveform design. Proper waveform design can handle fading through diversity

Waveform and Channel Relation

- For resolvable multipath groups, if each group is coming from a different angle (which is likely the case for some environments), Doppler spread becomes different shifts for each resolvable tap. Proper waveform design can handle this situation.
- Beamforming and narrow beam transmission can reduce Doppler spread, impacting the waveform design

Waveform and Channel Relation: Path Loss

- Path loss and shadowing impacts received and transmitted power.
- For a given range, when there is more loss, we need more power to compensate the loss.
- More power means Power Amplifiers. PA Power efficiency means PAPR, hence effecting the waveform design

Waveform and Channel Relation

- LOS and NLOS
- Polarization (cross polarization effect due to mutipath)
- Power delay profile (not only the delay spread, but also the power of the delayed paths, i.e. profile is effective in determining the right waveform)

Frequency selectivity (Delay spread) estimation: Importance

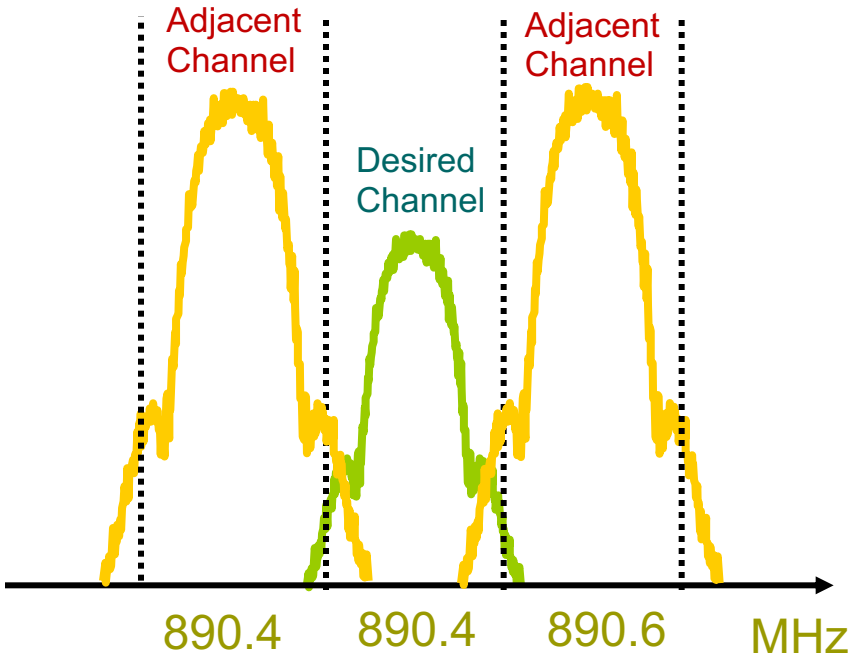
- Related to multipath power delay profile
- Related to data rate, amount of ISI, and equalization
  - The higher data rates, with narrower symbol durations experiences significant dispersion, requiring highly complex equalizers
- Examples
  - Narrowband systems
    - Adaptive demodulator
      - Equalizer or a simple detector
    - Adaptive equalizer
      - Number of channel taps needed for equalization might vary depending on channel dispersion
      - If channel is not dispersive, no need to increase equalizer complexity
      - Leads adaptive tap assignments
  - OFDM
    - Optimal channel frequency response estimation
    - Adaptive cyclic prefix (currently cyclic prefix is designed for the worst case dispersion)
    - Adaptation of OFDM symbol and number of carriers

INTERFERENCE

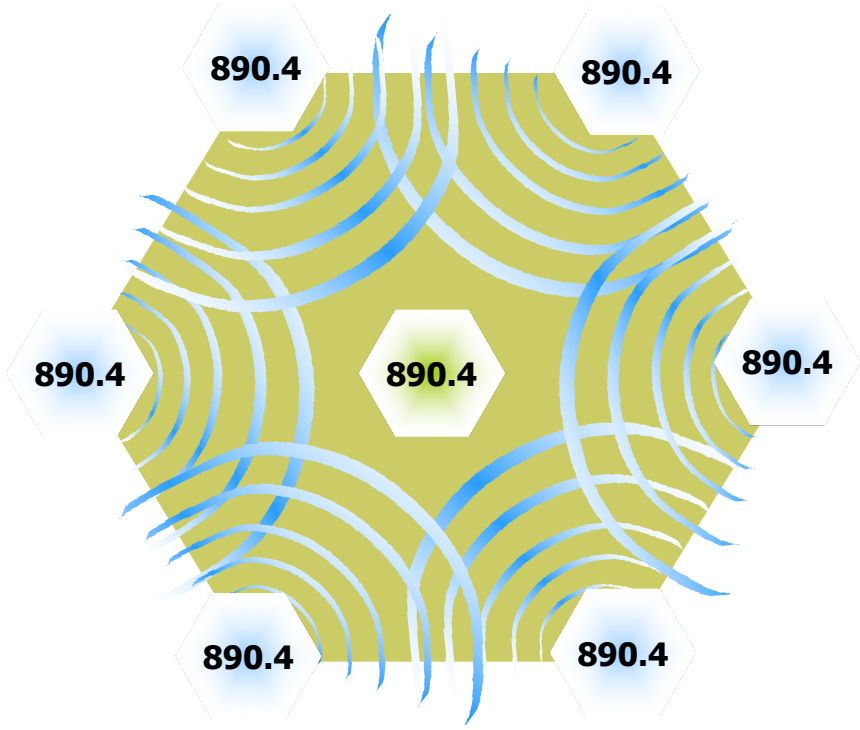
- Understanding the effect of intentional and unintentional interference
- Ability to generate interference
- Ability to visualize interference
- Ability to suppress (cancel) interference
- Understanding the effect of various interferences on different waveforms (like NBI in multicarrier or single carrier; or effect of CDMA in OFDM)
- Relation between interference and NOMA and non-orthogonal waveforms
- Ability to design NOMA (power based or code based NOMA)

Interference

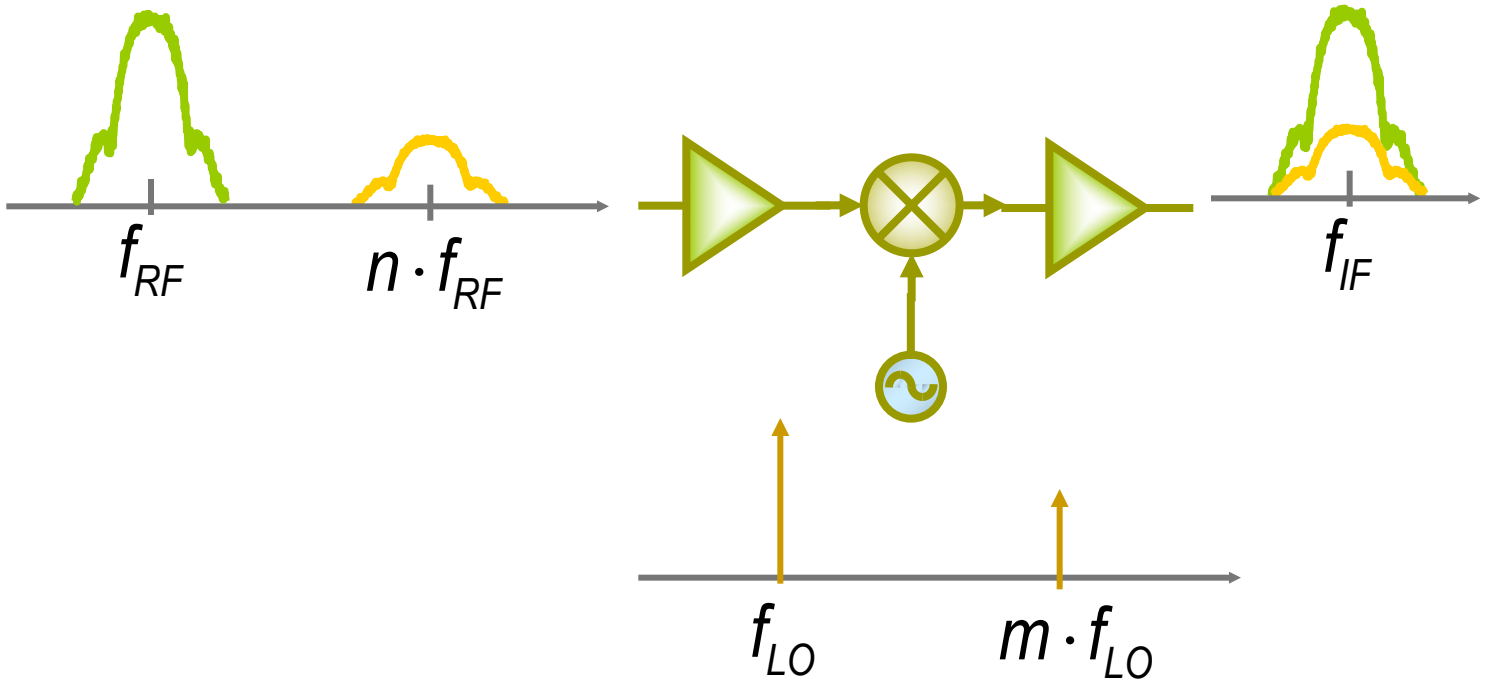
- Adjacent Channel Interference



- Co-Channel Interference

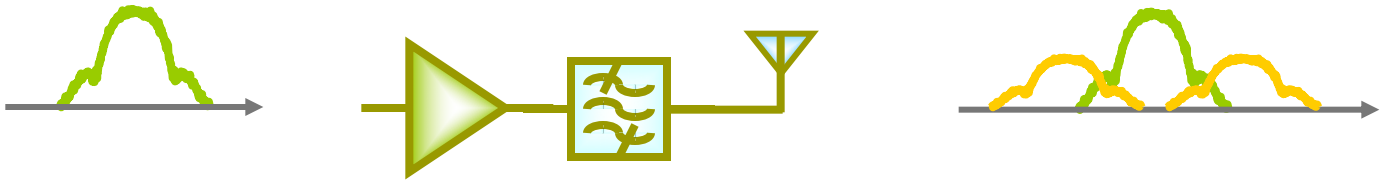


Spurious Response



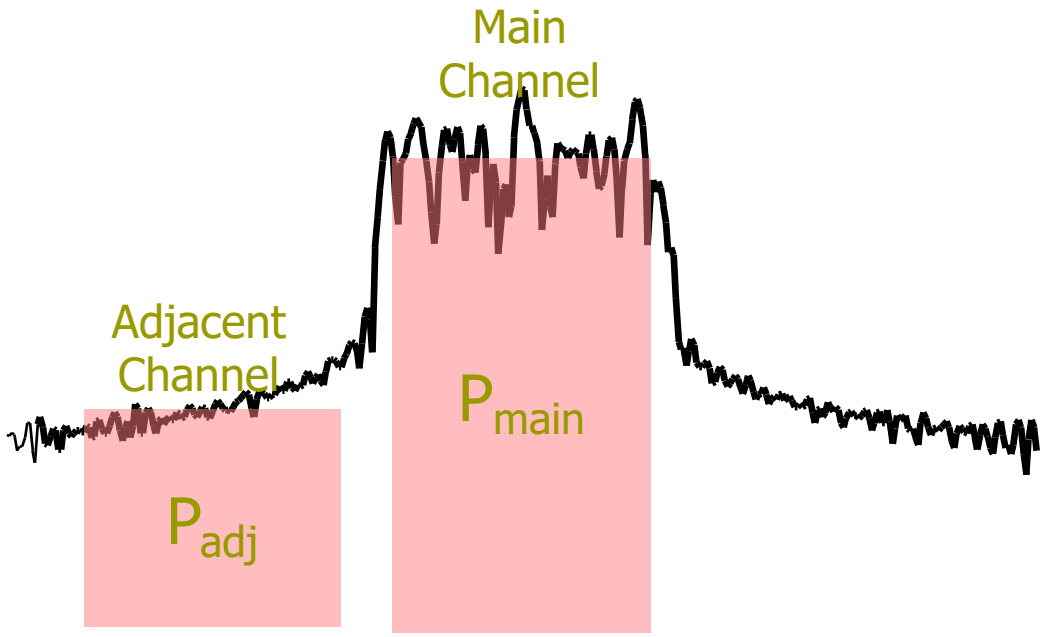
Transmitter Performance Spec.

- Output Power
- Spurious Emission
- Adjacent Channel Power Ratio; ACPR
- Frequency Stability



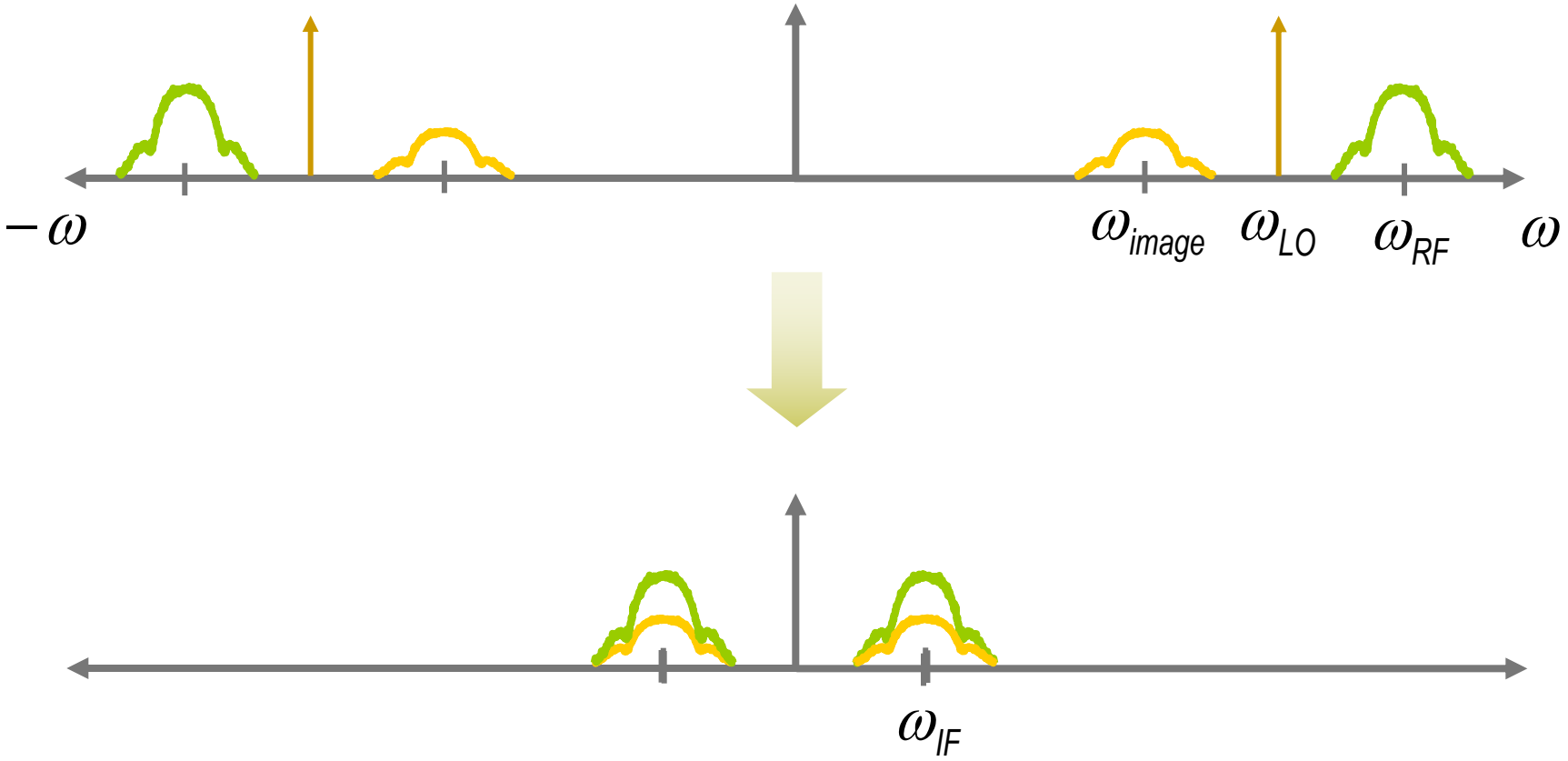
Adjacent Channel Power Ratio

- Definition depends on specification



$$ACPR = \frac{P_{adjacent}}{P_{main}}$$

Problem of Image Signal



Problem of Image Signal

- Solution: Image Rejection Filter