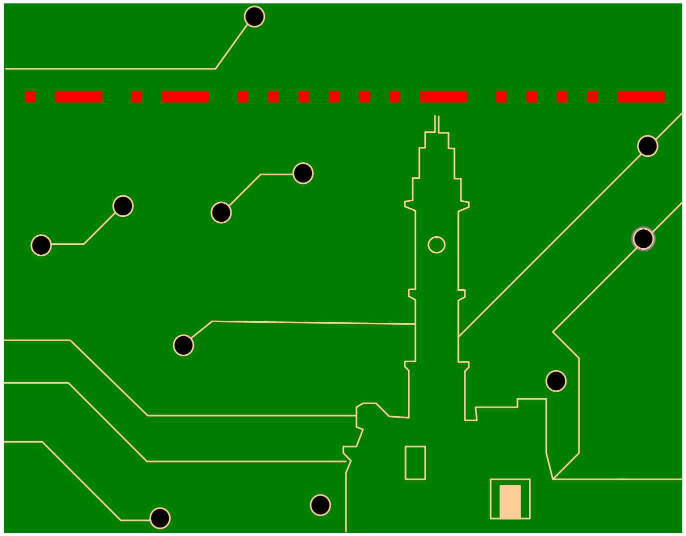
ΤΗΛ412 Ανάλυση & Σχεδίαση (Σύνθεση) Τηλεπικοινωνιακών Διατάξεων

Διάλεξη 5



Άγγελος Μπλέτσας

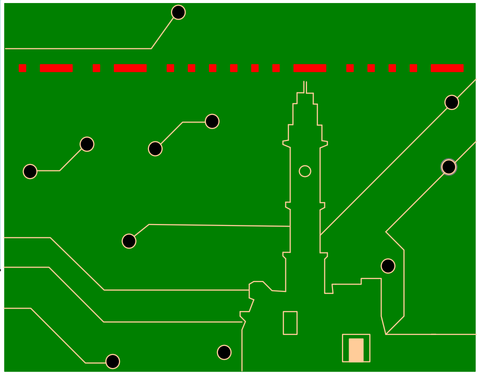
ΗΜΜΥ Πολυτεχνείου Κρήτης, Φθινόπωρο 2014

Lecture 6 – Receiver Architectures (cont'd)

Previous lecture: Filter Quality Factor Q, Heterodyne Receivers.

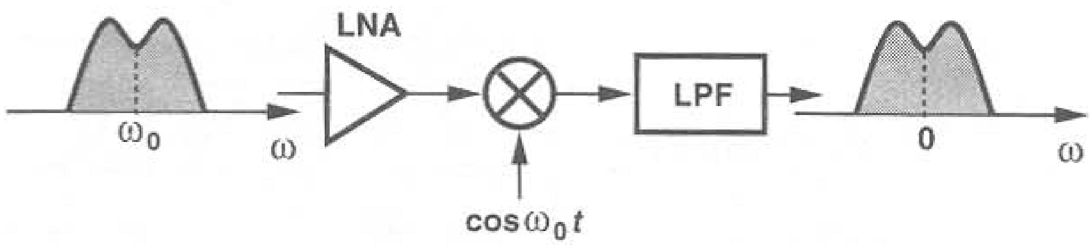
Today,

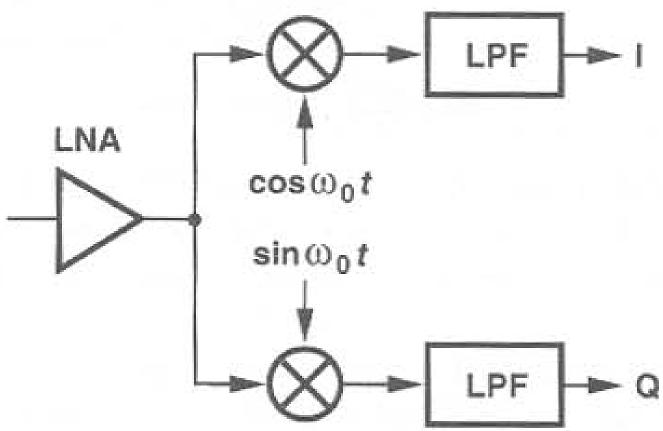
- Homodyne Receiver (and disadvantages)!
- Example of SuperHeterodyne (SuperHet) Receiver!
- Subsampling and Digital-IF Receiver.
- Dynamic Range of ADC.



1934 advertisement for Radio Engineering as a lucrative job!

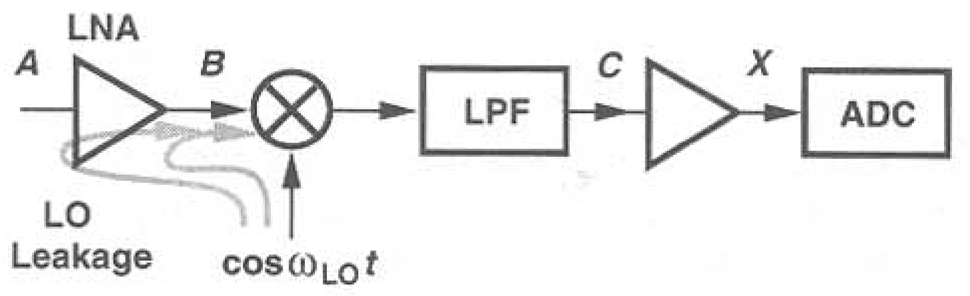
Homodyne (zero-IF) Receiver





- Directly convert to DC ($\omega_{LO}=\omega_{in}=\omega_1$, $\omega_{IF}=\omega_2=0$).

Basic Problems with zero-IF Receivers: <u>DC Offset</u>



- Big Problem: LO leakage due to capacitive and substrate coupling (or bond wire coupling if LO is provided through an external wire).

- The higher the frequency, the more obvious the effect.

- leakage => DC offset => saturation of following stages!

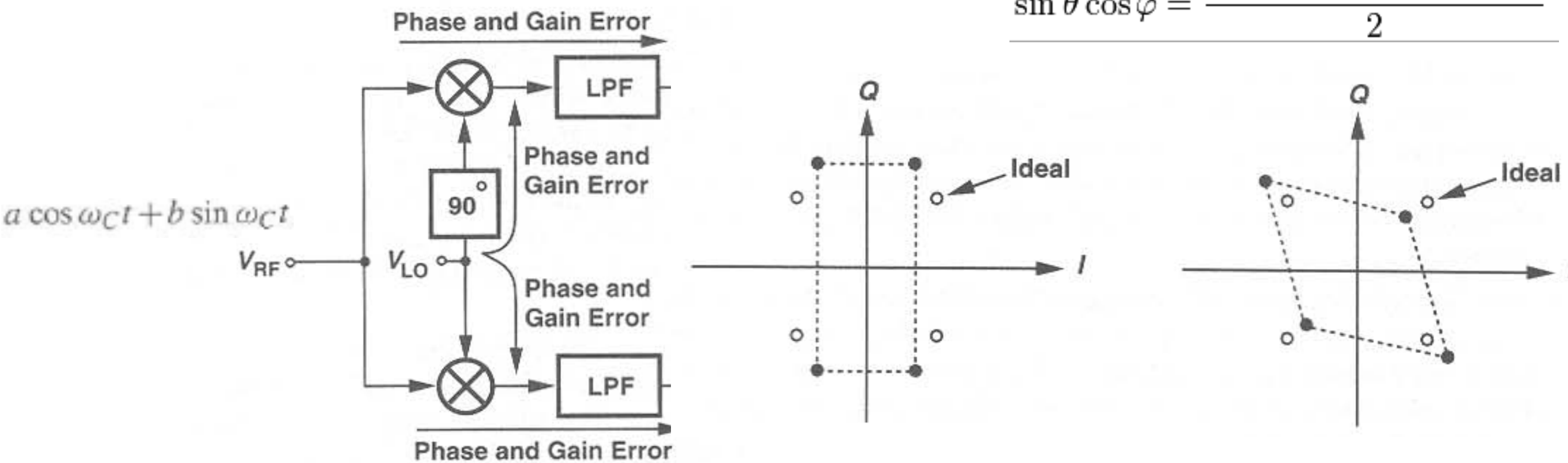
- possible solutions: DC-free coding or DC-offset removal.

Basic Problems with zero-IF Receivers: IQ Mismatch

$$\cos\theta\cos\varphi = \frac{\cos(\theta-\varphi)+\cos(\theta+\varphi)}{2}$$

$$\sin\theta\sin\varphi = \frac{\cos(\theta-\varphi)-\cos(\theta+\varphi)}{2}$$

$$\sin\theta\cos\varphi = \frac{\sin(\theta+\varphi)+\sin(\theta-\varphi)}{2}$$



$$x_{LO,I}(t) = 2\left(1+\frac{\epsilon}{2}\right)\cos\left(\omega_c t+\frac{\theta}{2}\right)$$

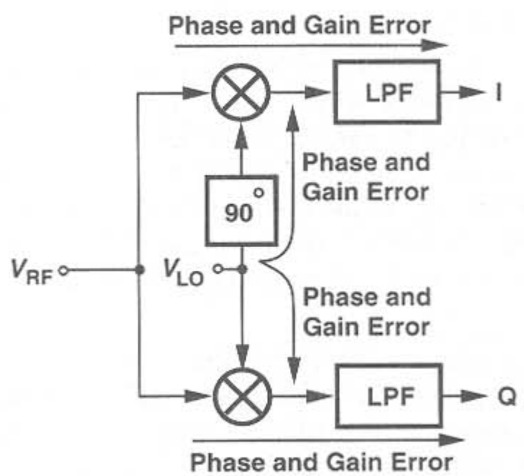
$$x_{LO,Q}(t) = 2\left(1-\frac{\epsilon}{2}\right)\sin\left(\omega_c t-\frac{\theta}{2}\right)$$

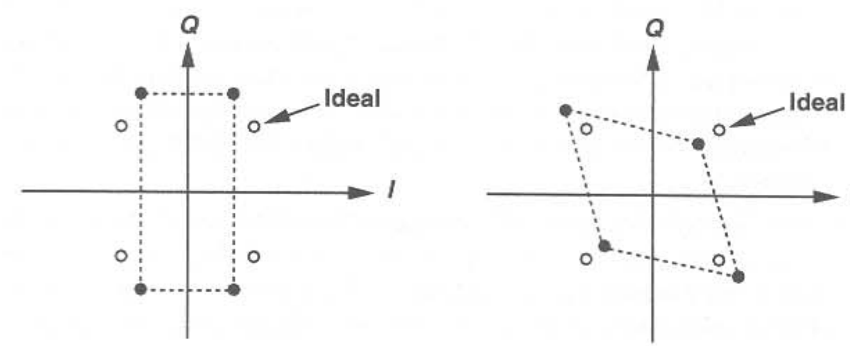
$$x_{BB,I}(t) = a\left(1+\frac{\epsilon}{2}\right)\cos\frac{\theta}{2} - b\left(1+\frac{\epsilon}{2}\right)\sin\frac{\theta}{2}$$

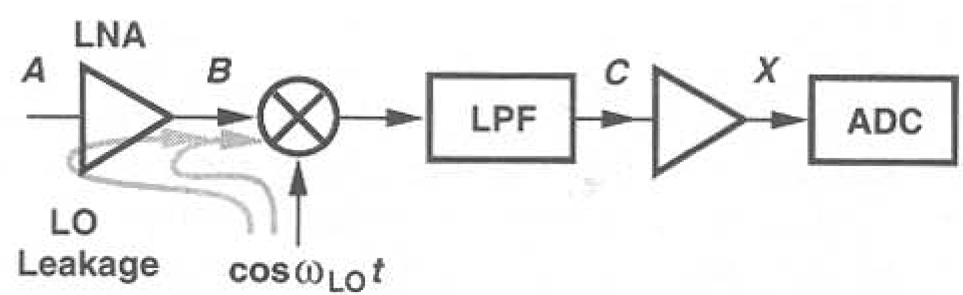
$$x_{BB,Q}(t) = -a\left(1-\frac{\epsilon}{2}\right)\sin\frac{\theta}{2} + b\left(1-\frac{\epsilon}{2}\right)\cos\frac{\theta}{2}$$

- Remember: The higher the (LO) frequency, the higher the parasitics (that is why this problem is smaller in heterodyne recs).

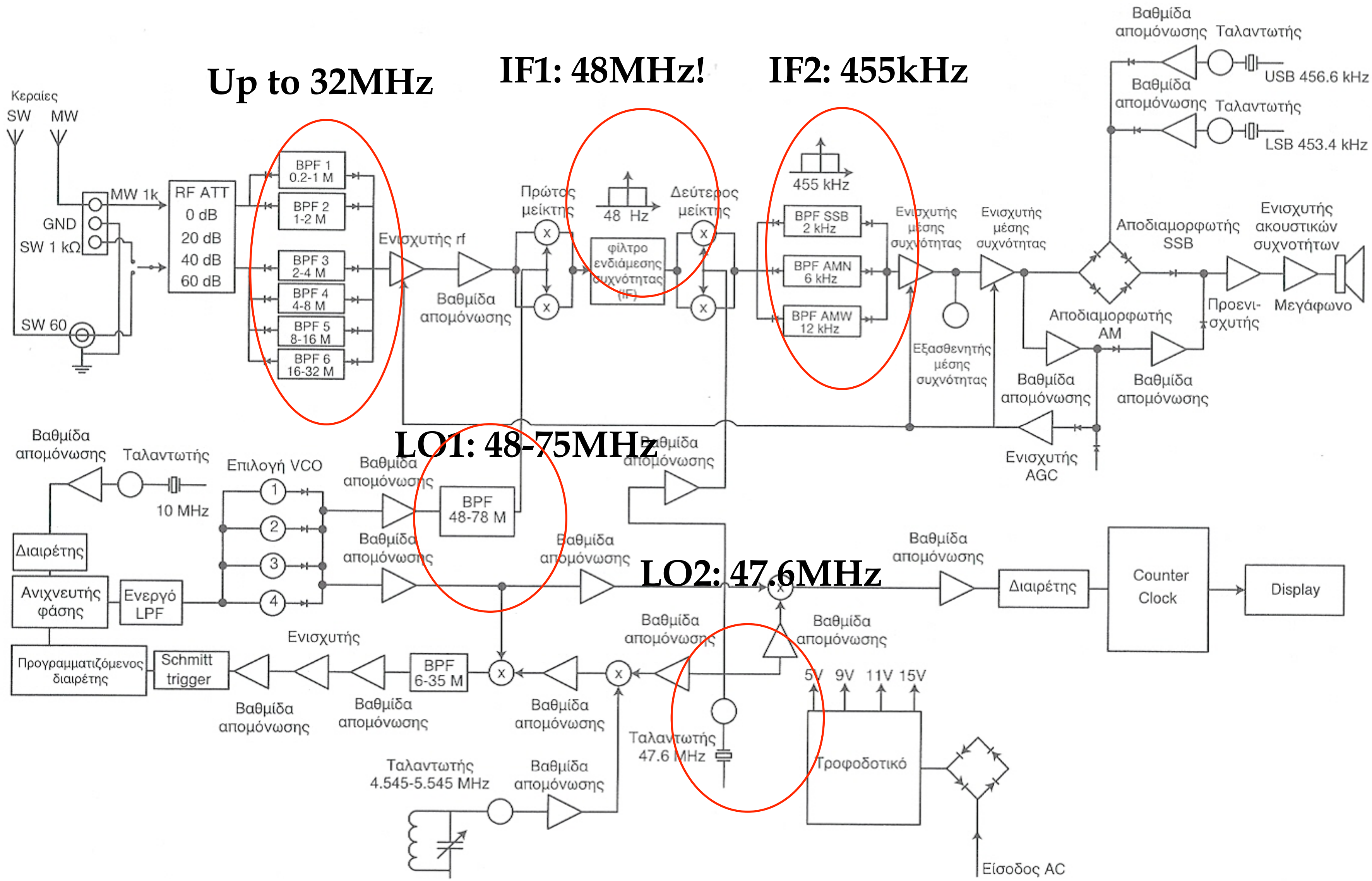
Basic Problems with zero-IF Receivers





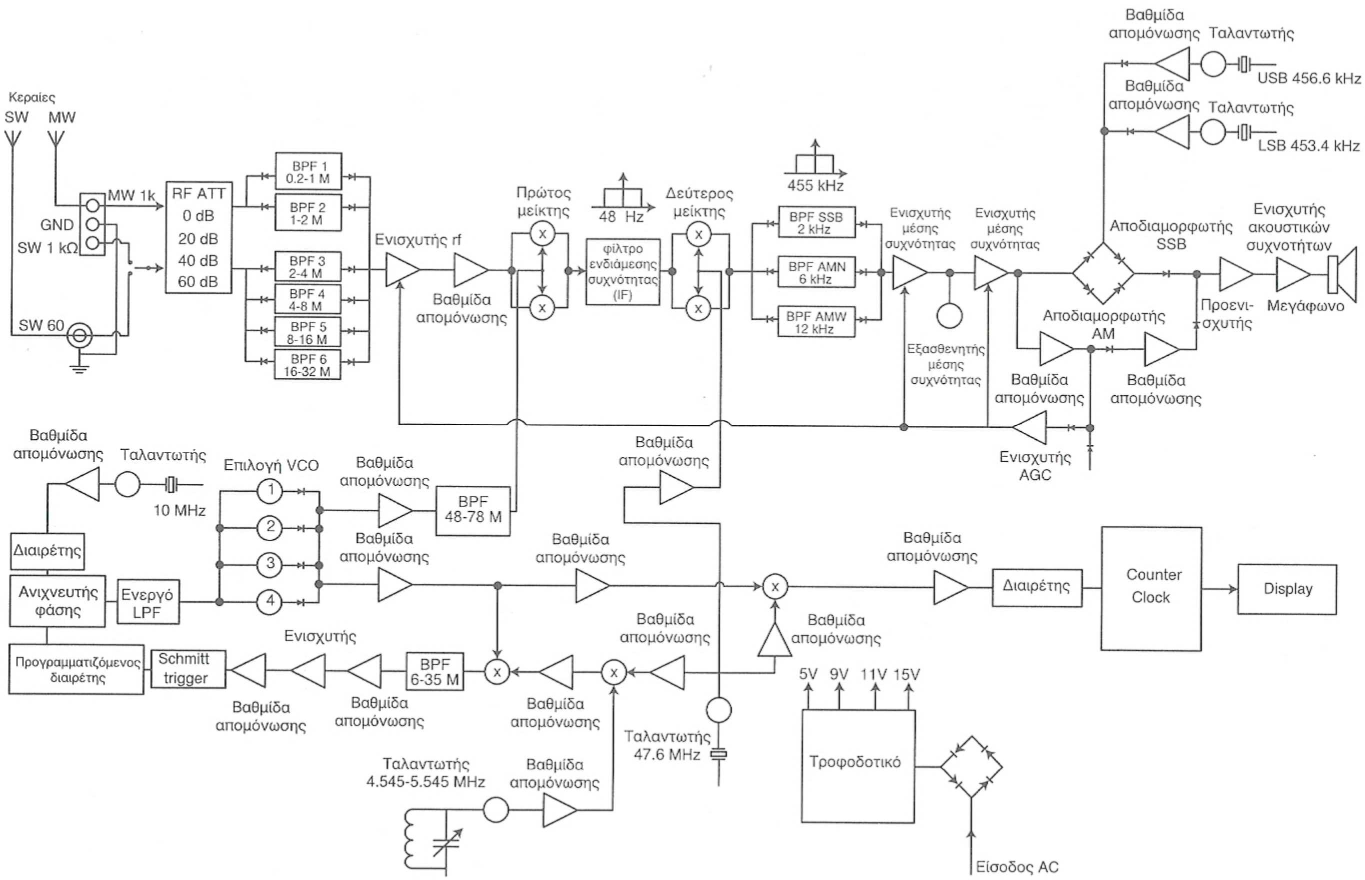


- Additional problems in zero-IF receivers: flicker (1/f) noise and even order distortion (close to DC).

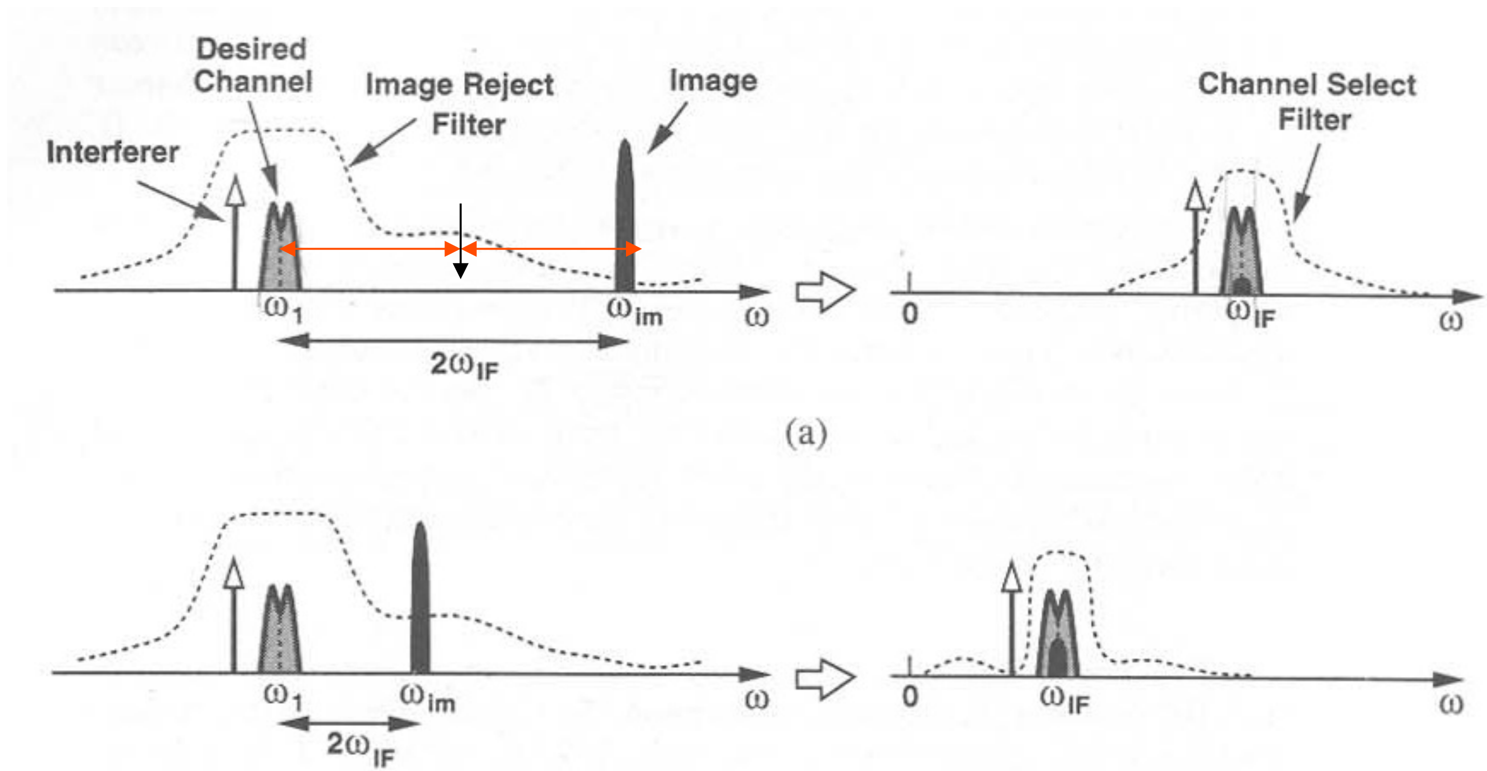


- Superheterodyne architecture: IF > signal freq!

What is the advantage of SuperHet?



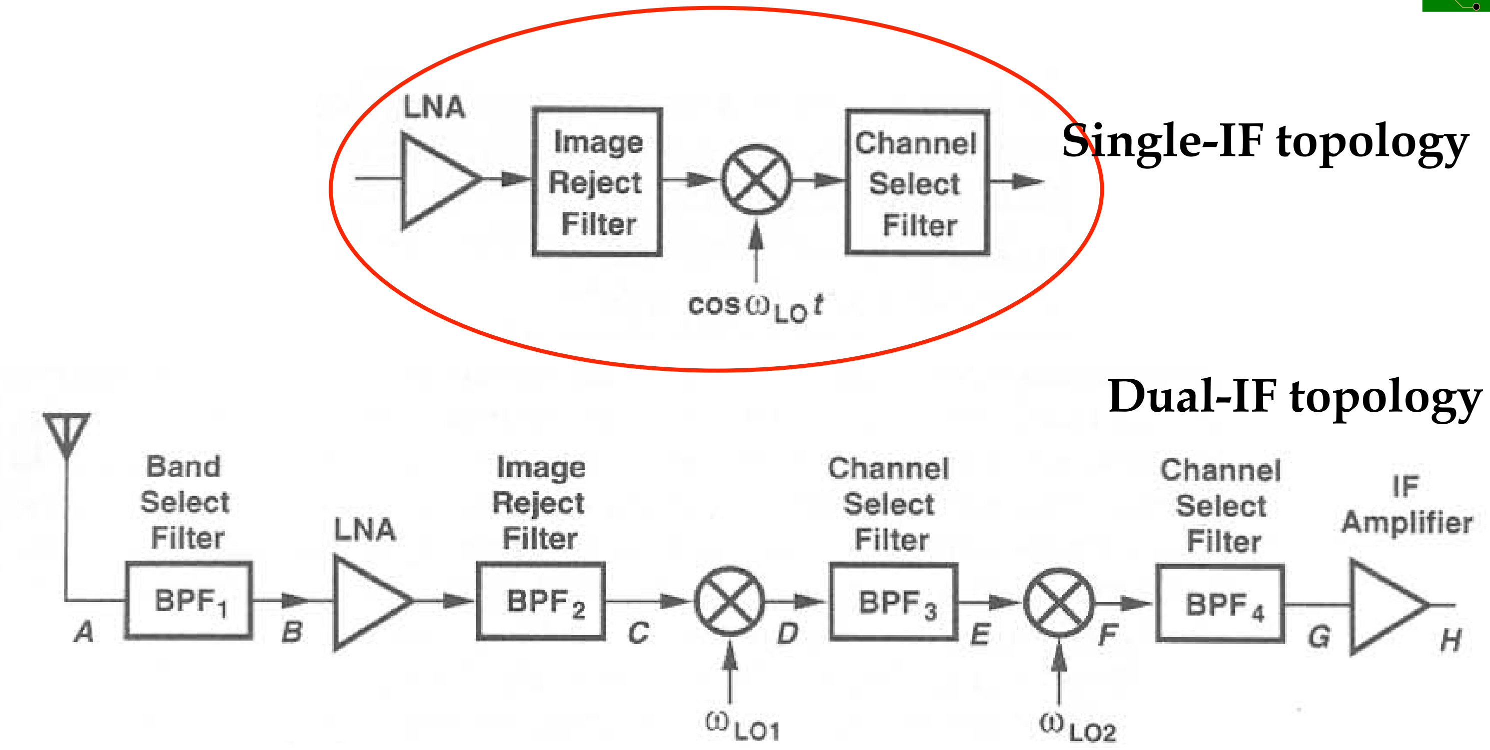
Heterodyne Receiver:
Selectivity vs Sensitivity Tradeoff



Not so simple, as it looks:

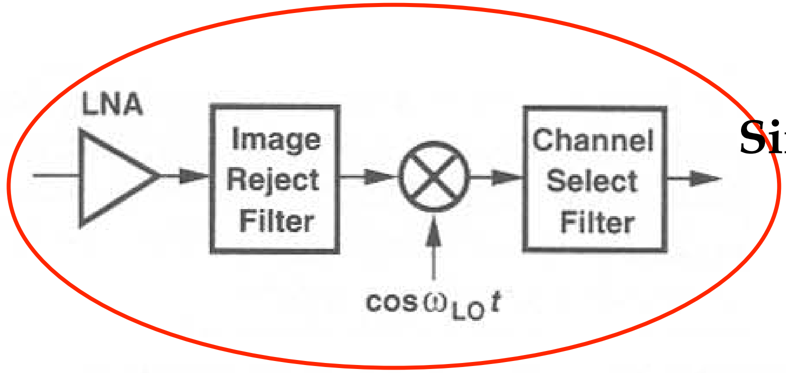
- higher ω_{IF} results to better image rejection (better sensitivity)…
- however, higher ω_{IF} results to worse channel selection (worse selectivity)!

Addressing the tradeoff: dual-IF topology



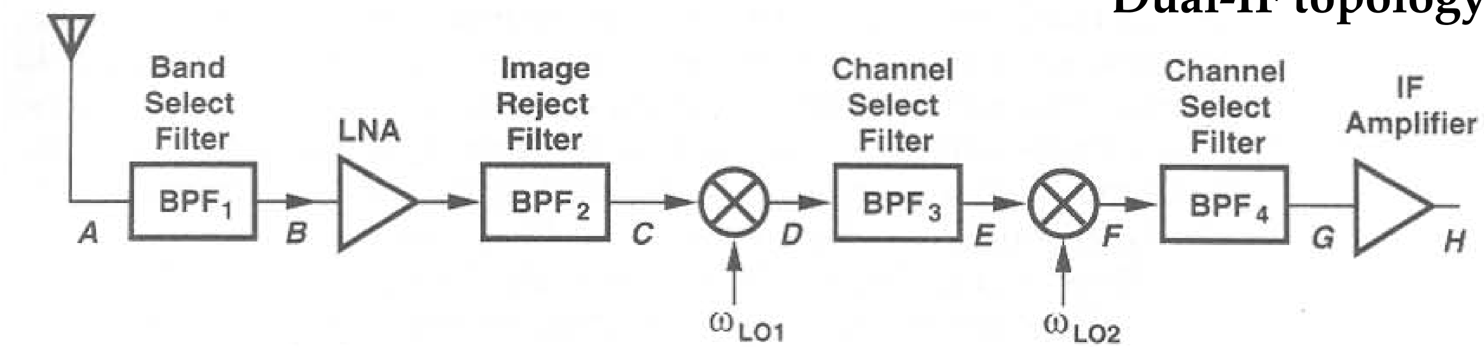
- up conversion: no limit on the IF frequency (as opposed to down conversion)…
- higher IF => better image rejection => better sensitivity…
- second conversion solves the selectivity problem!

Addressing the tradeoff: dual-IF topology



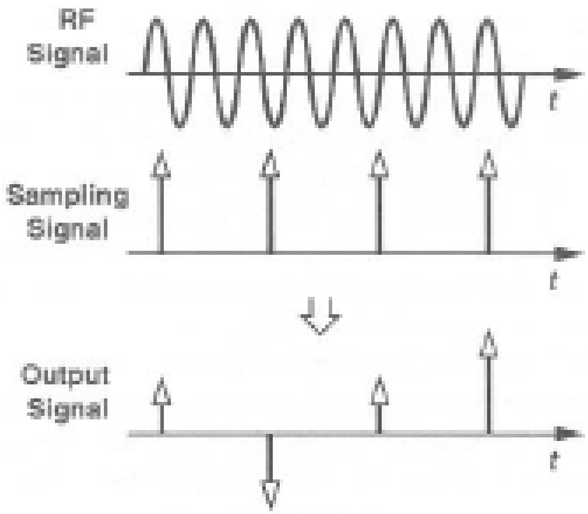
Single-IF topology

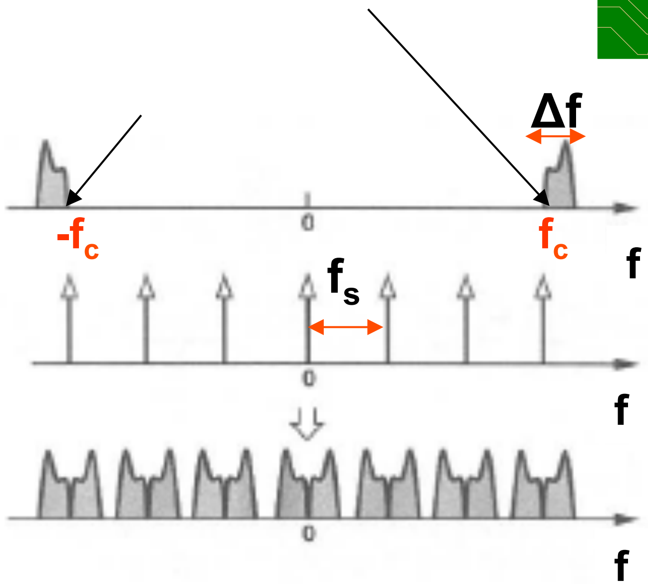
Dual-IF topology



- What about the image of the second IF?
- It exists in a smaller frequency than the LO2 and has been filtered by the first image reject filter or the first band select filter.
- It is also efficiently filtered by the last (low-center freq.) channel select filter!

Subsampling Receiver

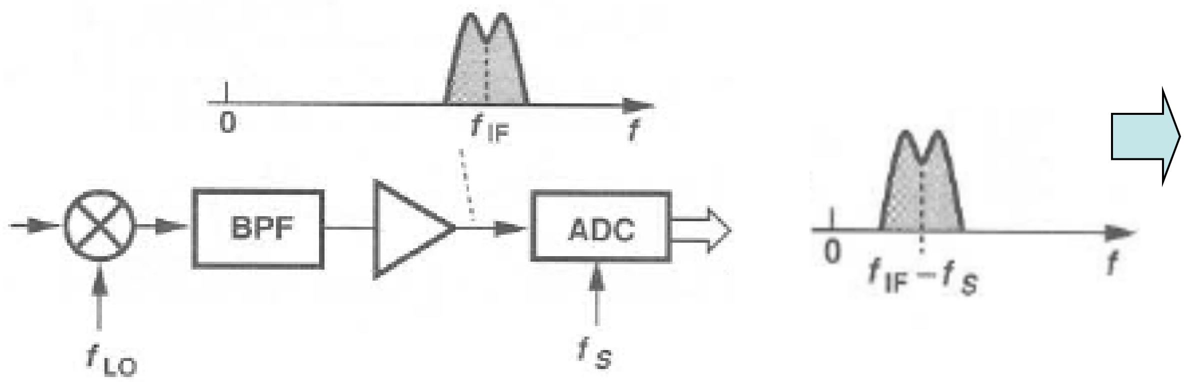




- For signal of passband BW Δf, sample with $f_s > 2\ \Delta f$.
- Usually, f_c=m f_s (m integer)…
- For narrowband signals, simplifies local oscillator design!
- Sampling circuit much simpler than mixer design…
- Major drawback: <u>aliasing of noise</u>

(down-converted noise is enhanced)!

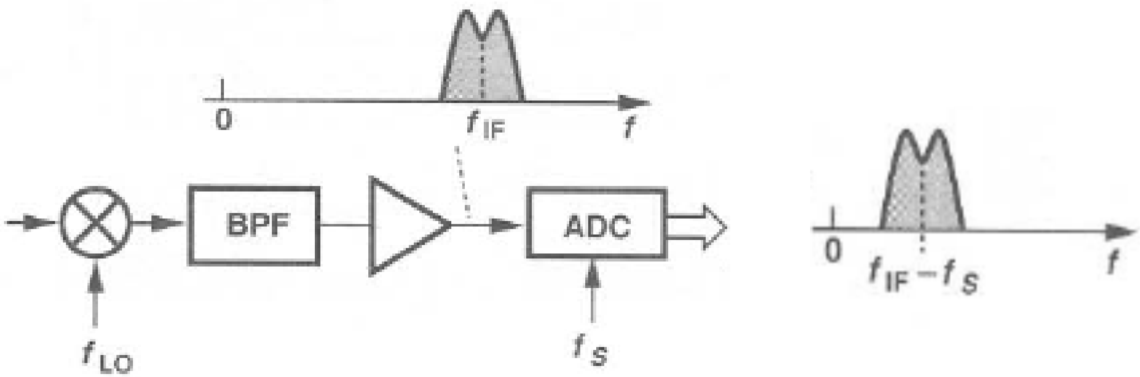
Digital-IF Receivers (no Signal Aliasing)



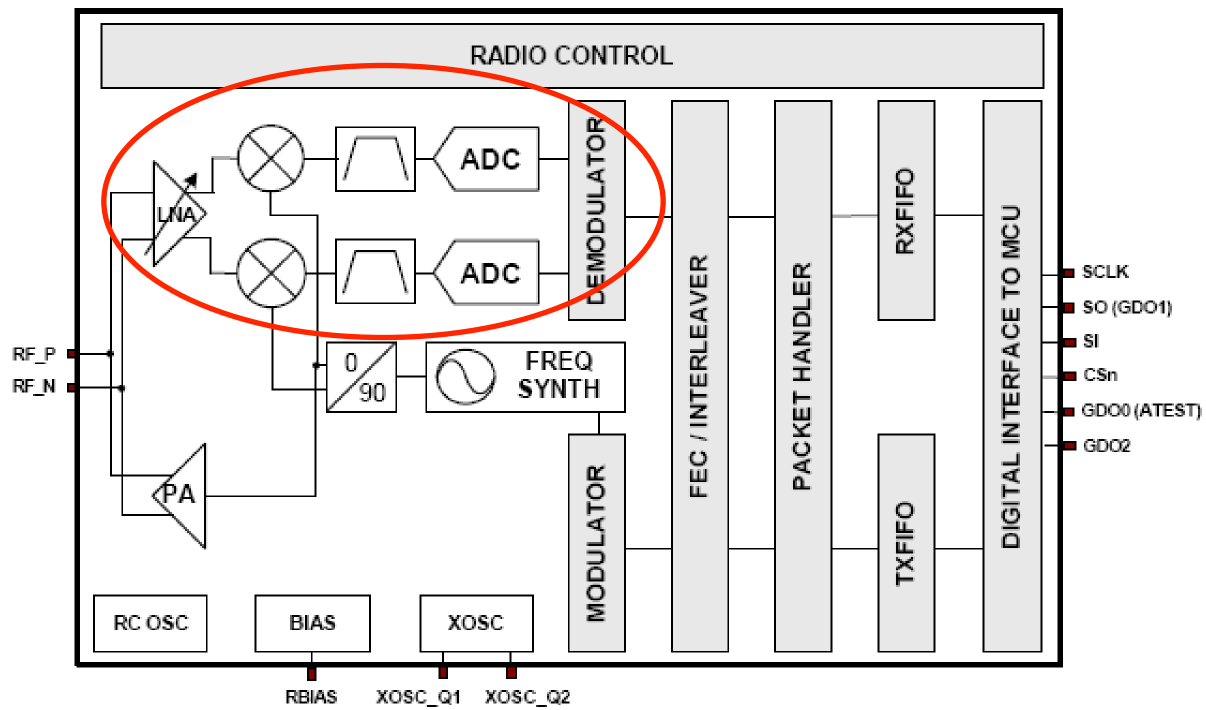
Quadrature mixing and filtering in DSP domain

- What if we sample at slightly smaller frequency than the IF?
- …get rid of Nyquist rate factor of 2 ($2f_{IF}$)…
- …still, sampling rate f_s is not negligible and requires speed and <u>linearity</u> (intermodulation products due to limited filtering affect performance)
- usually, in base stations where multiple channels need to be processed simultaneously…

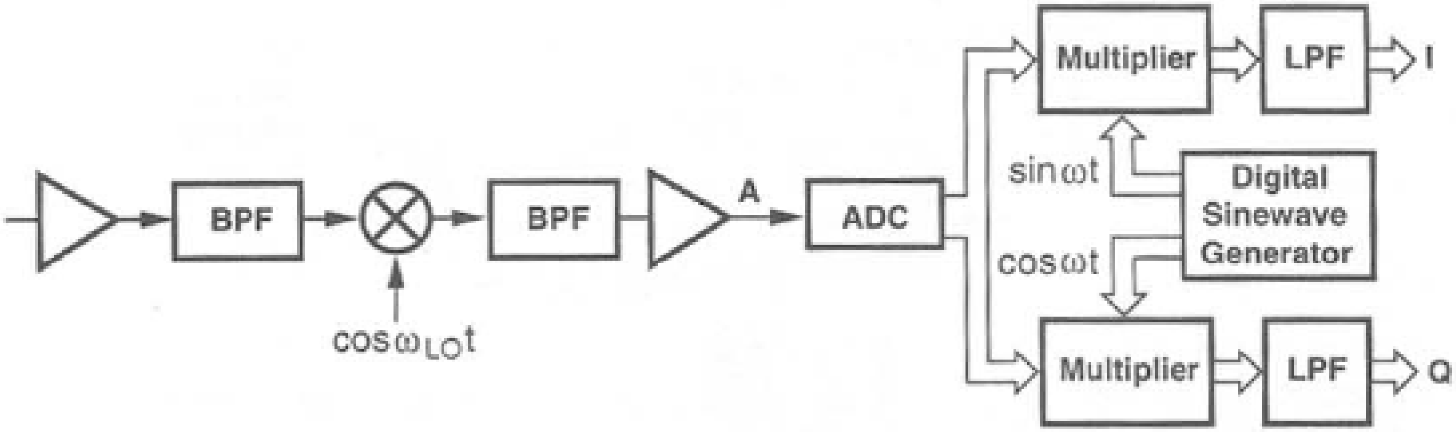
Ερώτηση: Έχετε χρησιμοποιήσει Digital-IF Receiver?



Απάντηση: cc2500



General Architecture of Digital-IF Receiver



- ADC must have small non-linearity

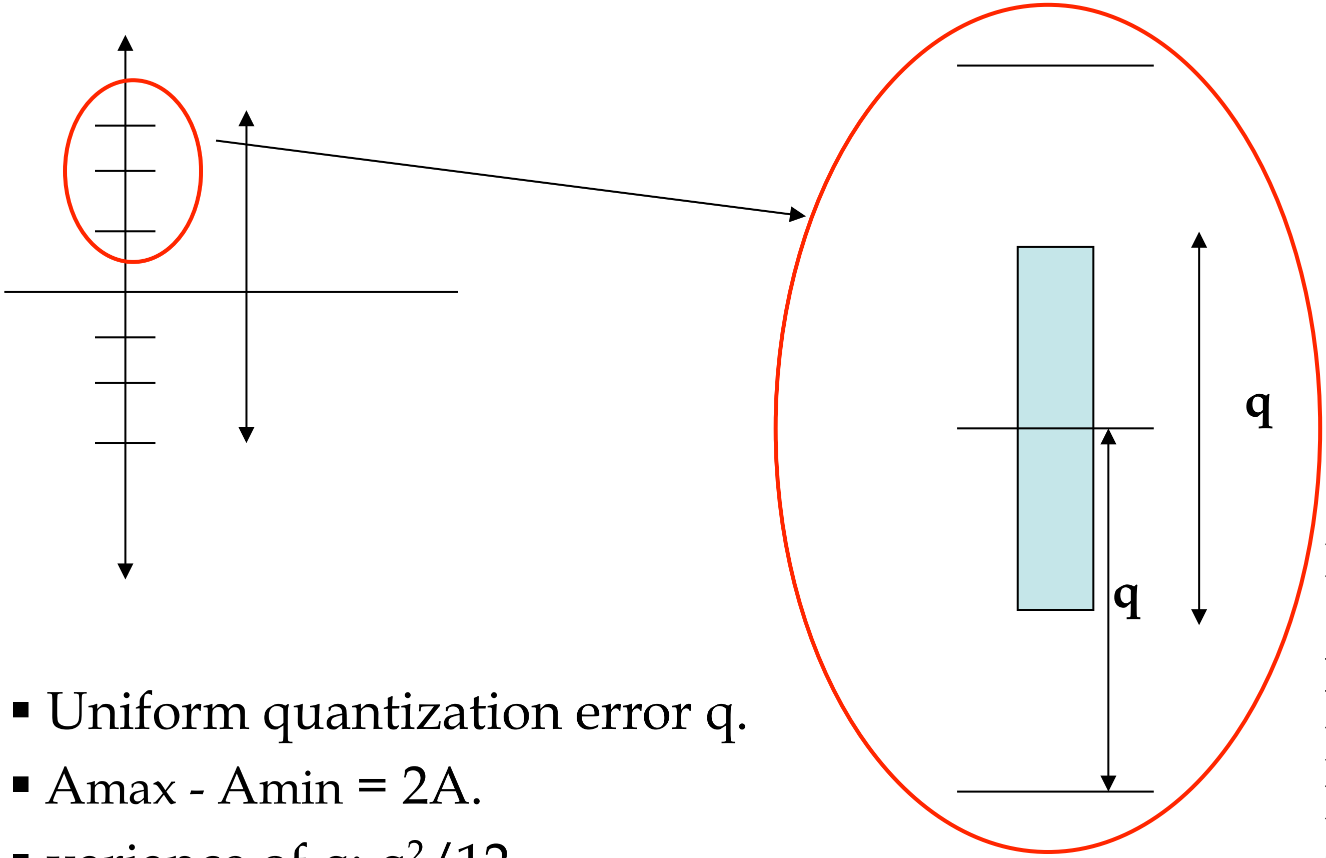
(in case the first BPF cannot suppress adjacent in frequency interferers).

- ADC must have high dynamic range

(to accommodate path loss and fading – AGC at LNA is highly desired).

- ADC must be fast and consume reasonable amount of power!

Dynamic Range of an ADC



More than 14 bits of dynamic range is hard to achieve in practice, even if power dissipation and cost are not an issue.

- Uniform quantization error q.
- Amax - Amin = 2A.
- variance of q: $q^2/12$
- $q = 2A/(2^n-1) \approx 2A/2^n \Rightarrow A = q\ 2^{(n-1)}$
- $S/N = (A^2/2)\ /\ (q^2/12) = 3\ 2^{(2n-1)} = 1.5\ 2^{2n} \Rightarrow 6n + 1.76$ [dB]

Questions?