Lecture 11: RF Filters

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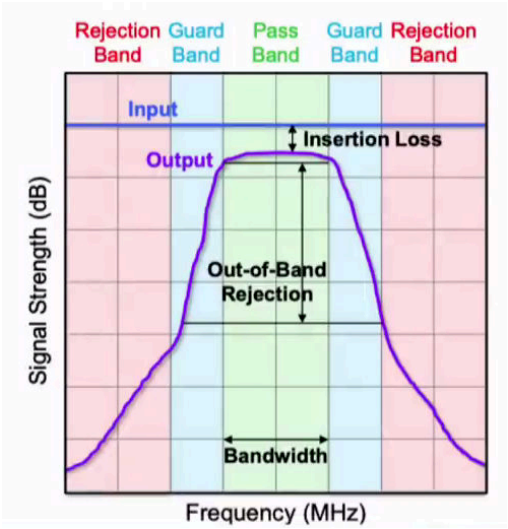
Watch Video

- https://www.youtube.com/watch?v=L8jmHtfVmPY
- *Title*: The iPhone Forever Changed the RF Filter

The iPhone Forever Changed the RF Filter

RF Filter Terminology



Quality Factor, Q

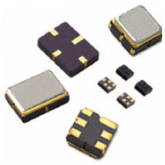
- Quality Factor, Q, is the ratio of center frequency to bandwidth of the BPF:

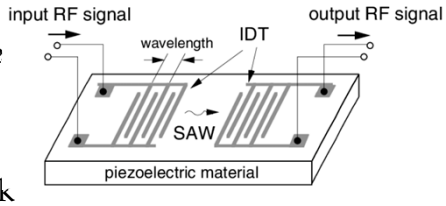
$$Q = \frac{f_r}{\Delta f} = \frac{\omega_r}{\Delta \omega}$$

- where f_r is the resonant frequency (center frequency) and Δf the half-power bandwidth.
- High Q factor and low insertion loss are desired for RF Filters.

Popular IC-based RF Filters

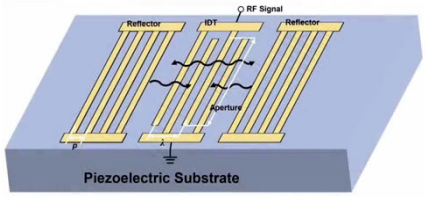
- **SAW Filter**: Surface Acoustic Wave Filter.
- Convert electrical energy into acoustic (mechanical) energy on a piezoelectric material.
- Interdigital transducers (IDTs), which are interleave metal electrodes on either end of the device, convert the electrical signal into an acoustic wave and then back to an electrical signal.





SAW Filters

- Compact (small), easy to manufacture, low-cost.
- Mainly used below 3GHz.
- Spacing of the electrodes determines the operating frequency of the SAW filter.



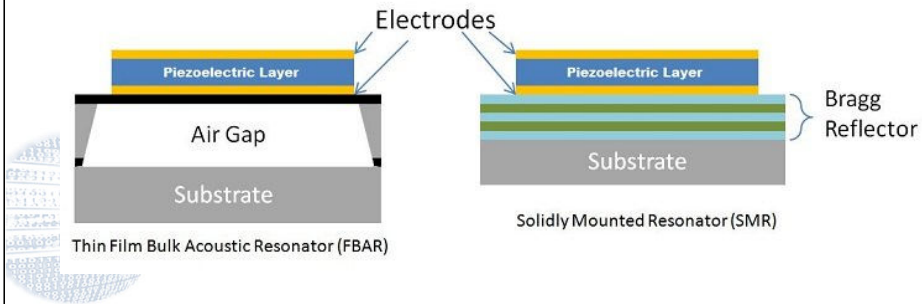
- SAW Resonator-based filters use extra reflectors.
- Middle-class smartphones for specific regions use 14 or 15 RF filters, while premium models with global compatibility may adopt as many as 30 to 40 RF filters.

Bulk Acoustic Wave (BAW) Filters

- BAW filters move the acoustic wave through the bulk of the piezoelectric material, not just on its surface.
- Can operate at higher frequencies (up to 6 GHz).
- Still compact and low-cost, but more expensive than SAW filters (since they are harder to build).
- Used for the new 4G and 5G bands above 1.9 GHz.
- BAW filters can reduces cross talk between filters, and are less sensitive to temperature changes.

BAW Filter Subtypes

- Thin-Film Bulk Acoustic Resonator (FBAR or TFBAR).
- Solidly Mounted Resonator (SMR).



FBAR Advantages

Filter Type Bandpass
Frequency Band > 3 GHz
Acoustic Wave Velocity 11,300 m/s (typ)
Piezoelectric Material AlN, ZnO
Packaging e.g. 1.1x1.4 mm² footprint, flip-chip

