# RF Duplexer

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# History and actual status

**Duplexer:** enables the simultaneous transmission & reception of RF waves by isolating the two signals in time and frequency domains, using only one antenna.

**70's**: film bulk acoustic resonator (FBAR): free-standing membrane prevents acoustic wave from escaping to substrate, limited by piezo-electric thin-films technologies

**80's:** surface acoustic wave (SAW), up to 1GHz

**90's:** breakthrough thanks to thin film technology, bulk acoustic wave (BAW) solidly mounted resonator (SMR)

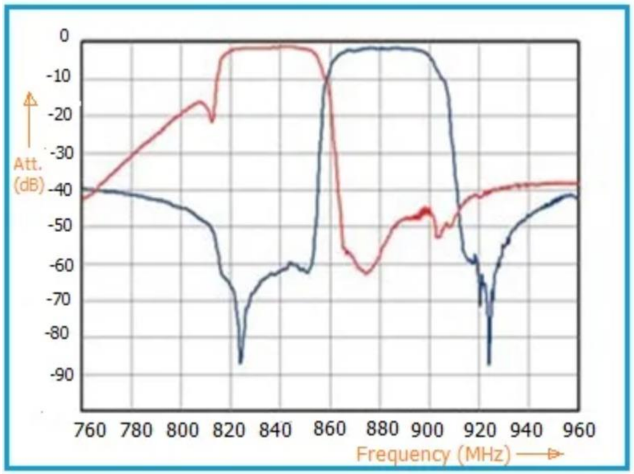
**1997**: Qorvo's first product
**2001:** integration in smartphones and infrastructure

- increasing demand for efficient RF components
- high-speed wireless communication and deployment of 5G networks
- Temperature drift compensation

# MEMS operation principle

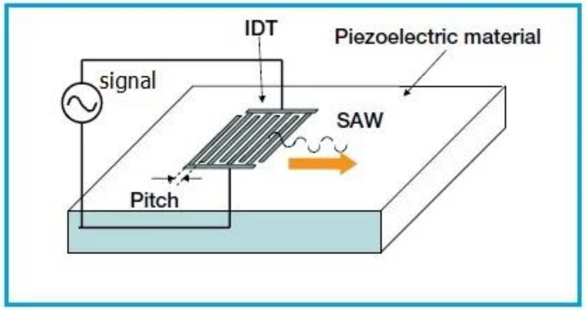
**Duplexers:**

- Acoustic wavelength much shorter than EM wavelength (µm vs cm)
- Lower voltage than typical MEMS,
- Integrated with CMOS




**SAW**

$$f_0 = \frac{V_{SAW}}{\lambda}$$




**BAW**

$$f \propto \sqrt{\frac{E}{\rho}\frac{n}{t}}$$

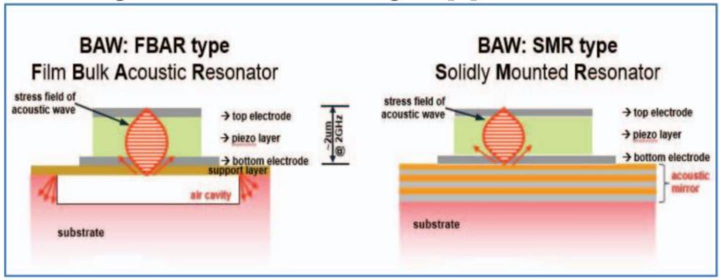



Fig.1. FBAR vs SMR basic fabrication difference

***Images courtesy of:*** https://www.rfwireless-world.com/Terminology/SAW-Duplexer-basics-and-working-principle.html
https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7329587
**Piezo scaling class by Dr. Shea in the Scaling Laws course**

# MEMS implementation

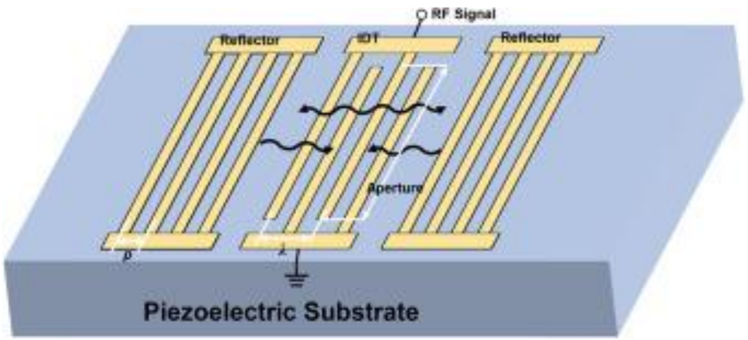
**Typical micromachining used for fabrication**

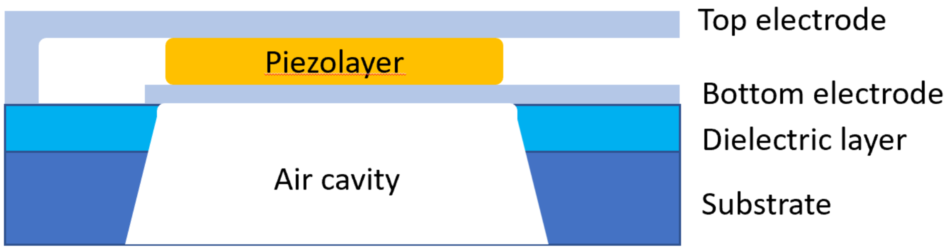
**Rayleigh waves highly dependent on substrate material surface**

**Aluminium nitride gaining traction for its properties vs ease of fabrication**

**Photoresist patterning & etching, thin film metal deposition, release for BAW membrane**

**Packaging to reduce losses & provide mechanical protection**




*Images courtesy of: K. Yang, C. He, J. Fang, X. Cui, H. Sun, Y. Yang, C. Zuo, Advanced RF filters for wireless communications. Chip 2, 100058 (2023)*
*https://en.wikipedia.org/wiki/Thin-film_bulk_acoustic_resonator*

# Characteristics

- Balanced type or Unbalanced type
- Pass Band frequency ranges
- Bandwidth Insertion Loss (dB)
- Absolute rejection (dB)
- Isolation between Tx to Rx (dB)
- Size
- Out-of-band attenuation
- Temperature stability

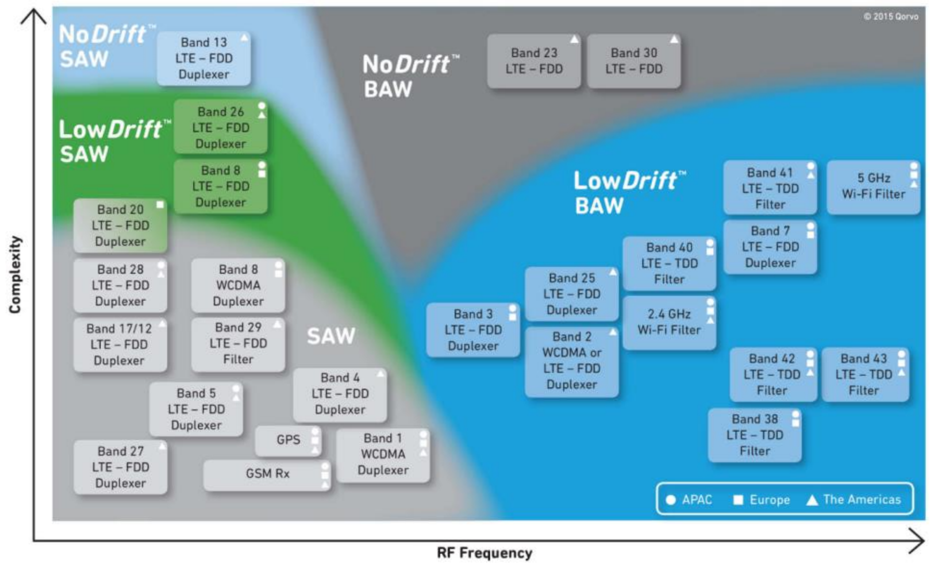



Table 1. Band and feature developments over time.

| | | LTE Advanced | | 5G |
|---|---|---|---|---|
| **Features** | **2015** | **2017** | **2019** | **2020** |
| Number of total RF paths | 14 | 22 | >100 | >300 |
| Number of filter-band paths | 7 | 12 | 18 | >25 |
| Maximum number of filters combined at one node for carrier aggregation | 2 | 6 | 8 | 15 |
| Critical isolation specifications required to meet standard | 2 | 36 | 51 | 74 |
| Max bandwidth of transmit signal | 20 MHz | 40 MHz | 60 MHz | 100 MHz |
| Power class 2 (3 dB higher power) | No | No | Yes | Yes |
| LNA integration | No | No | Yes | Yes |
| Envelope tracking or average power tracking (ET or APT) | APT | ET | ET | ET & APT |
| Incremental RF PCB size change | Baseline | +25% | +50% | -35% |

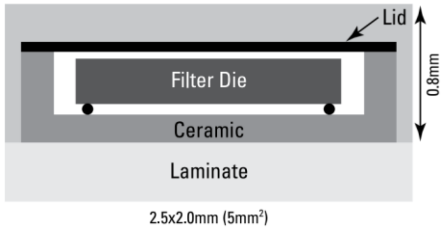
qorvo



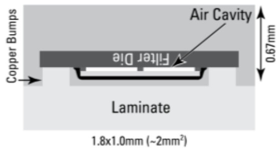
***Images courtesy of:*** https://www.rfmw.com/data/qorvo_rf_filter_apps.pdf

# Packaging and systems integration

- Flip-chip with copper bumps to replace wire bonds
  - Plug and play placement
  - Better RF performance
  - Fast manufacturing and assembly
- Ceramic packaging replaced by Wafer-level packaging
  - Die protected in air cavity by polymer seal
  - High-frequency operation and mechanical protection
- Reduce the area by placing the pillars on the WLP roof (-30%)
  - 1.1x0.9x0.585mm

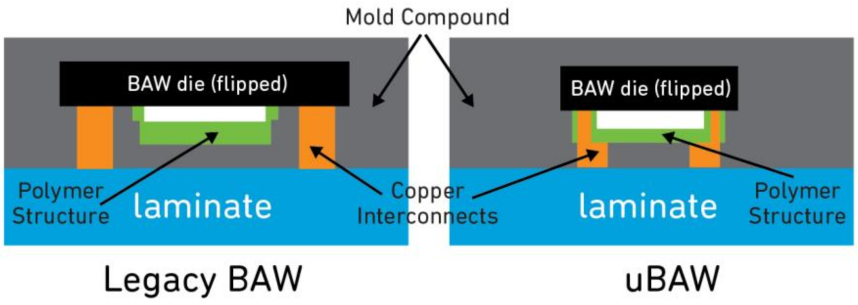



Typical Wafer Packaging




Wafer Level Packaging

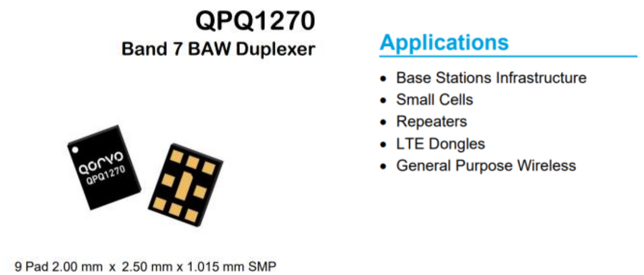
Figure 8. Simplified cross-section of legacy WLP BAW versus uBAW.




***Images courtesy of:*** ***https://www.rfmw.com/data/qorvo_rf_filter_apps.pdf*** **,** https://www.qorvo.com/resources/d/qorvo-advanced-baw-filter-technology-impact-on-5g-white-paper

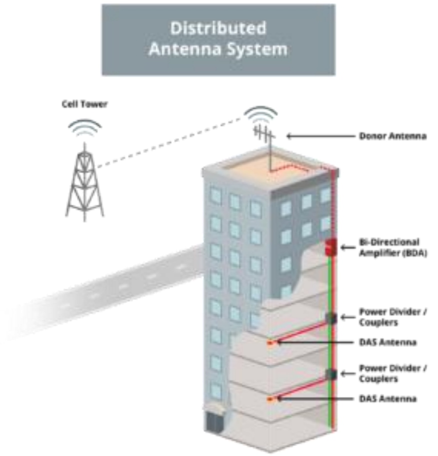
# Products and current applications

Femtocells and picocells

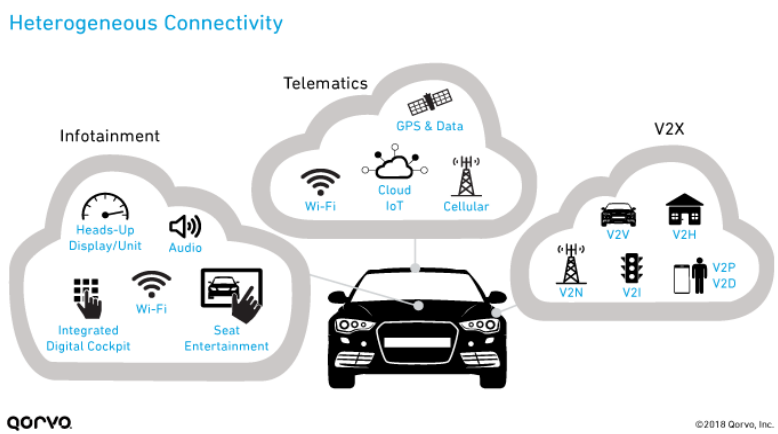




SAW: 2G, 3G, Bluetooth, GPS
BAW: 4G, 5G




Boosters, repeaters and distributed antenna systems (DAS)


routers

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***K. Yang, C. He, J. Fang, X. Cui, H. Sun, Y. Yang, C. Zuo, Advanced RF filters for wireless communications. Chip 2, 100058 (2023)***

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