SPECTRUM CONTROL

High Power SAW Filters

Re-thinking High Power SAW Filters:

How Innovative Design Techniques are Creating a New Generation of SAW Filters for Modern Military, Space, and Commercial Systems

Overview

Mitigating interference, which has been a concern since the first RF system was designed, has become even more critical in modern military, space, and commercial systems. Three market factors are creating significant challenges for engineers in controlling interference in today's designs:

- *RF "Sewage"* – The overcrowding of the RF spectrum due to the predominance of commercial and military/aerospace systems utilizing multiple technologies has "polluted" the spectrum.
- *Technology Integration* – Military, space, and commercial systems are integrating digital and analog technologies in the same package, creating greater interference concerns.
- *System Shrinkage* – Modern communications systems are becoming more compact and lightweight. Budgets are becoming tighter. Evermore stringent Size, Weight, Power and Cost (SWaP-C) parameters are leading to greater interference issues.

To address the current market challenges, filtering techniques on the RF front-end of printed circuit boards (PCBs) take on a greater significance. Surface Acoustic Wave (SAW) filters have been employed for decades but many traditional SAW filters have been unable to address the high-power RF surges from many sources common in modern systems.

A new generation of SAW filters, however, is creating a design paradigm and helping RF engineers effectively address interference. The SAW devices better meet the needs for high-power communications systems by efficiently overcoming the challenges associated with analog-digital systems that have very precise power requirements and sharper specifications.

These filters remove undesirable signals that otherwise will adversely affect radar, communication, and electronic warfare (EW) systems. An advantage of high power SAW filter technology is the realization of parts with reduced size and weight at a lower price than comparable filter technologies since the same process equipment that IC manufacturers rely upon can be adapted to manufacture a SAW product.

Evolution of SAW Filters

SAW filters have proven to be an effective design element to mitigate interference for decades. They convert electrical energy into acoustic or mechanical energy on a piezoelectric material. A transducer generates a tuned acoustic wave to amplify the desired signal and attenuate all others. Each transducer is composed of periodic interdigital electrodes connected to two bus bars.

The bus bars are connected to the electrical source or load. A single interdigital electrode acts as an acoustic source or detector. Amplitude is determined by the electrode length, and phase is given by the electrode's position. The wavelength (λ) of the electrodes and neighboring spaces determines the operating frequency for the SAW device.

One key advantage of SAW filters is they have large rejection bandwidths, so they can filter out closely adjacent signals. Other benefits are that SAW filters are known to have low insertion loss and high selectivity.

While SAW filters have excellent performance in low-power applications, similar success has proven elusive in emerging high-power designs. As EW, base stations, radar, and similar communications systems became digitized and operate at higher frequencies with greater bandwidth, conventional SAW filters were unable to address the associated high input power. RF energy would heat up the SAW filters to such an extent that they would become "electronic popcorn" and literally fly off the board. For all intent and purposes, the SAW filter behaved as if it was an RF fuse.

Advanced SAW Filter Technology

All of that has changed. Spectrum Control leveraged its decades of filtering expertise to develop a new generation of SAW filters (Figure 1) that support high input power. Its team of engineers applied an innovative materials science approach and advanced substrates to create SAW filters that meet the high output demands of modern systems.

Figure 1: *Advanced materials science and substrates has led to a new generation of SAW filters that support high input power up to +35 dBm CW at +125° C.*

By using a solutions-based design approach, the SAW filters can handle up to 5x as much power as previous SAW filters. Engineers took a fresh look at every aspect of SAW filter development and found methods to improve their performance:

- *Innovative Materials Formula* – Spectrum Control developed a proprietary materials formula along with another lite layer of Al creates improved thermal conductivity at higher power levels while maintaining bandwidth and low insertion loss.

- *Advanced Substrates* – The main substrates used in the SAW filter are lithium niobate (LiNbO3) and lithium tantalate (LiTaO3). These inorganic compounds are highly effective options to mitigate Alkali-Silica Reaction (ASR) and make the filters very durable and rugged. For certain higher frequency requirements, synthetic diamond, thin film, and glass substrates can be used, as well.

- *Packaging* – Filters and oscillators are hermetically sealed in the SAW filter. Oscillators have fundamental frequencies up to 1200 MHz, which provides superior phase noise performance and vibration sensitivity. This approach maintains environmental integrity to pass the rigors of MIL-STD-883 Method 1014 Conditions A & C for both gross and fine leak detection.

- *Advanced Development* – In-house, state-of-the-art SAW wafer fab technology and proprietary simulation software are used to ensure reliable design. The result is consistent, repeatable responses, eliminating the need for tuning typically required for filters.

Taking this approach allows the SAW filters to serve as a drop-in replacement for current low RF power handling SAW filters, saving time and money. No custom PCB layouts for thermal considerations are required and standard reflow profiles can be used. It can also lead to smaller board designs in some systems.

High-Power Performance

The innovative design and materials science break new ground for SAW filters. The devices achieve high power input up to +35 dBm continuous wave (CW) at +125° C and cover narrow, wide, and fractional bandwidths across frequencies of 20 MHz to 1.6 GHz. This level of performance is achieved without degradation of the filter's key parameters, including center frequency, bandwidth, insertion loss, and ripple.

It is important to note that the SAW filter’s high

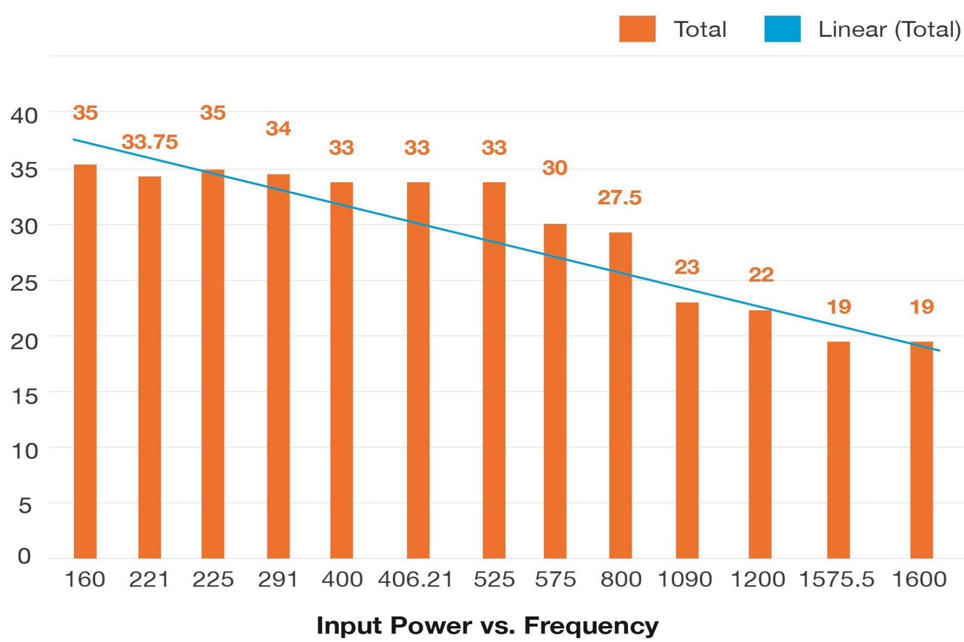

Figure 2: *Spectrum Control high power SAW filter power input handling capabilities vs center frequency.*

input power is tested at CW. Since peak power is pulse-based, it not an accurate depiction of real-world environments. Because CW is constant, it more precisely replicates how the filter will handle power when integrated in a system designed for base stations, radar systems, electrical grids, and other commercial and military use cases.

Maintaining High Quality Standards

Ensuring reliable performance in the most stringent and mission-critical applications requires more than innovative design. The highest quality control standards must be maintained at every stage of the product ecosystem, from initial design through manufacturing and delivery. All processes must have a high level of quality assurance. Spectrum Control maintains an ISO 9001-certified facility, including material and screening standards, strict lot traceability, and continuous monitoring over all parameters critical to product quality and development.

To ensure reliability and consistency, automated test systems driven by dedicated software developed in-house are used. Every SAW filter is electrically tested for critical parameters, such as center frequency, insertion loss, bandwidth, and rejection. Characterizing SAW filters at 125° C and CW for 1,000 hours gives engineers confidence that they will meet commercial and space specifications.

Figure 3 shows results of SAW devices that went through rigorous testing. The devices were tested for 760 hours at +37 dBm (5 watts) at 125°. Input power for both samples was initiated at +33 dBm. Power was steadily increased, as shown in the plots on the right side, until +37 dBm was reached.

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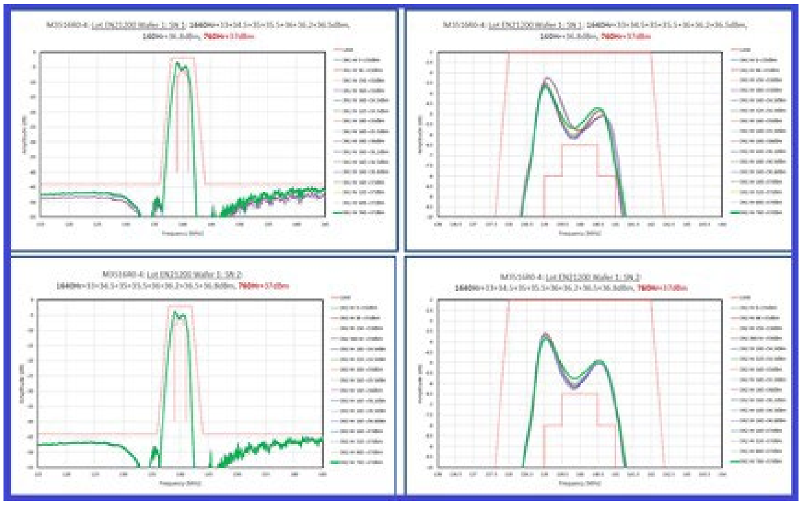

Figure 3: *High power SAW filters undergo extensive testing to verify performance.*

Figure 4 shows results of SAW devices that went through rigorous testing. The devices were tested for 760 hours at +37 dBm (5 watts) at 125°. Input power for both samples was initiated at +33 dBm. Power was steadily increased, as shown in the plots on the right side, until +37 dBm was reached.

SAW v. Alternative Filtering Techniques
The new high power SAW filters are a much more viable design option to mitigate interference compared to alternative techniques engineers have had to settle for in their designs. All three of those alternatives – bulk acoustic wave (BAW) filters, hybrid filters, and lumped elements – have their limitations.

- *BAW Filters* – A common alternative, BAW filters support frequencies above 1.4 GHz. At lower frequencies, however, performance suffers, limiting the applications in which they can be used. Additionally, BAW filters handle power in a more ineffective manner. The acoustic wave is channeled through the bulk of the substrate, requiring the metallized structures and substrates to be stacked on top of each other. In a SAW filter, the acoustic wave is channeled across the top of the substrate surface.

- *Hybrid Filters* – A hybrid solution integrates a passive filter with an active filter. The passive power filter addresses the low order harmonic current while the high order harmonics are addressed by the active power filter.

- *Lumped Elements* – Lumped element filters are passive filters that consist of the necessary inductors (Ls), capacitors (Cs), and resistors (Rs) for the specific design requirements.

All these approaches have one major problem – they are much bigger than a SAW filter. In fact, they take up 3x-10x more space on the PCB than a SAW filter. SAW filters are also lighter and more cost-efficient compared to other filter technologies, which makes them superior options for today's designs.

Meeting Today's Systems Needs
The ability of the new SAW filters to achieve input power of +35 dB (compared to +20 dB for conventional SAW filters) make them ideal for emerging space, commercial, and military systems, including those in table 1, that rely on digital technologies and clean transmissions. In particular, they are a perfect complement for designs with low noise amplifiers (LNAs) that integrate analog technologies.

Two examples – one commercial and another military – highlight the challenges of mitigating interference and the need for advanced filtering techniques in modern applications.

Antenna Arrays	Military Radar
Base Stations	Military Radio Communications
Commercial Critical Infrastructure (EMS/Fire/Police)	Satellite
Electronic Warfare (EW)	Smart Grid Communications

Table 1: *Common applications for high power SAW filters.*

- *Smart Grid* – The electrical grid is undergoing a monumental transformation from antiquated to cutting-edge. Today's smart grids are built on three layers – energy, communications, and virtual. Numerous nodes scattered throughout the utility transmit an enormous amount of data between layers. Given the highly volatile environment of the electrical grid, unintentional interference must be addressed. Smart grids are also targets for nefarious activity. SAW filters are necessary to help mitigate interference and prevent blackouts that would leave millions of people without electricity.

- *EW Systems* – Compact designs with greater capability utilizing advanced digital technologies define modern EW. Because oftheir size and pricing advantages, as well as their ability to be a drop-in replacement, high-power SAW filters effectively address SWaP-C requirements enacted by the Department of Defense (DoD).

Conclusion

Increased RF sewage from an overcrowded RF spectrum, coupled with a mixture of analog-digital technologies in smaller designs are creating increased interference in a growing number of commercial, military, and space designs. Spectrum Control's high power SAW filters enable higher power and tighter bandwidths. They are compact in size (as small as 3 x 3 mm LCC) to accommodate existing board designs and operate over a wide temperature range of -40° C to 85° C, providing an efficient solution to modern interference concerns.