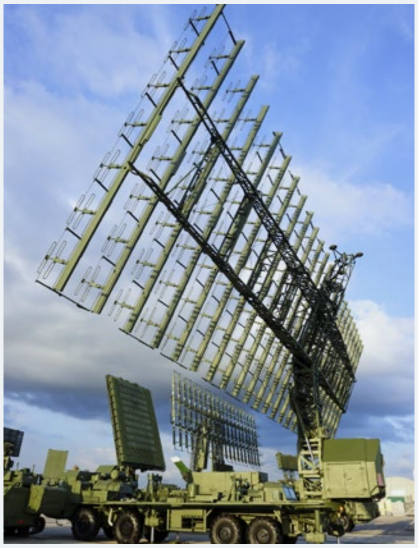
TECH BRIEF

Advantages of Suspended Substrate Stripline Microwave Filters

ERZIA

Contents

Introduction

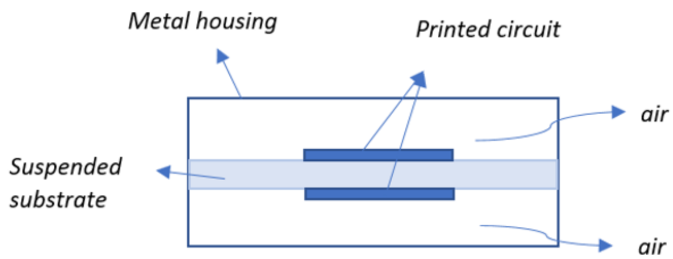


Filters are key components in any RF/microwave system. From mobile networks to the most sophisticated military RADAR, every single device needs at some point to select or reject specific frequencies of the RF spectrum. The different technologies to implement this functionality have been evolving along with the RF technology. There are several technologies available nowadays to implement different types of filters. Each one can offer advantages in terms of insertion loss, selectivity, size, fractional bandwidth, power handling, etc.

DESCRIPTION

Air is a good choice to implement a filter: it features almost no dielectric loss and stable dielectric constant over temperature. SSS consists of transmission lines printed onto both sides of a thin substrate, which is in turn suspended in air between two ground planes, as shown in **Figure 1.**

Figure 1: *Suspended Substrate Stripline Cross Section*

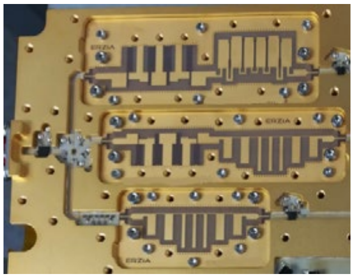


This configuration constitutes an air stripline in which most of the electric fields propagate through air rather than the supporting substrate, enabling higher unloaded quality factors as compared to other planar technologies such as microstrip or dielectric stripline. SSS filters are therefore more stable over temperature since the critical sections are realized in air, so the dependence of the substrate material on the temperature has a negligible effect. This results in a very small temperature dependence for the device.

From a realization point of view, the range of impedances is wider than either microstrip or dielectric stripline, which allows both lower-loss (wider) lines and higher fractional bandwidths. Moreover, lower band-edge insertion loss is obtained for a same skirt selectivity thanks to the use of the generalized Chebyshev prototype. This response has the additional advantage of allowing high rejection levels closer to the passband. Finally, thanks to the shielded structure, RF leakage is minimized, and hermetic designs are assured.

SSS filters are suited to military environments as SSS structures have been successfully tested under shock and vibration conditions.

Figure 2: *Suspended Substrate Stripline filters integrated in a microwave system (left) and as stand-alone module (right)*



From a packaging perspective, SSS filters can be directly integrated in a system, or shipped as stand-alone connectorized modules for flexibility (see **Figure 2**).

Finally, the performance of SSS filters shows to be highly repeatable.

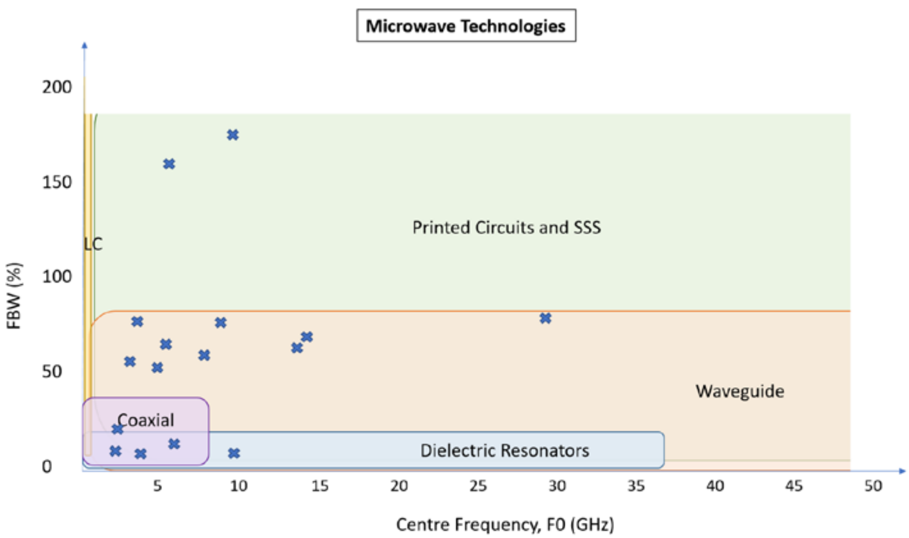
The main advantages of SSS filters are summarized as follows:

- Selectivity
- Size
- Low loss
- Temperature stability
- Repeatability

PERFORMANCE

Figure 3 shows the approximate range of center frequency and fractional bandwidth (FBW) for different filter technologies such as waveguide or dielectric resonators. It is important to mention that this is indicative for illustrative purposes and not strict limits. Blue crosses correspond to SSS filters developed by ERZIA, used to illustrate the coverage area of this technology.

Figure 3: Centre Frequency and Fractional Bandwidth for different filter technologies. ERZIA SSS COTS filters are marked with blue crosses.



As observed, SSS offers a competitive solution both for narrow and broadband designs at frequencies ranging from 0.5 to 50 GHz, covering areas that are traditionally reserved to waveguide and dielectric resonators.

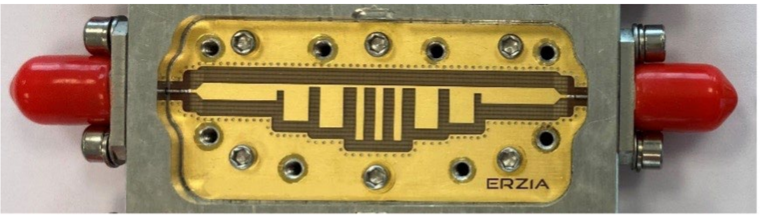
Broadband filters

Three examples of broadband filters are presented next. In fact, two of them are lowpass filters with a cut-off frequency of 10 and 18 GHz, respectively, and the third one is a highpass filter from 18 to 40 GHz. All of them feature a multi-octave flat response, very low insertion loss and sharp band edges, providing a rejection above 80 dB. The three examples have been compared with a counterpart available on the market using a different technology. An intensive research has been done to find the most performant alternative matching the frequency response and specially to the cut-off frequencies.

Lowpass filter from 0 to 10 GHz

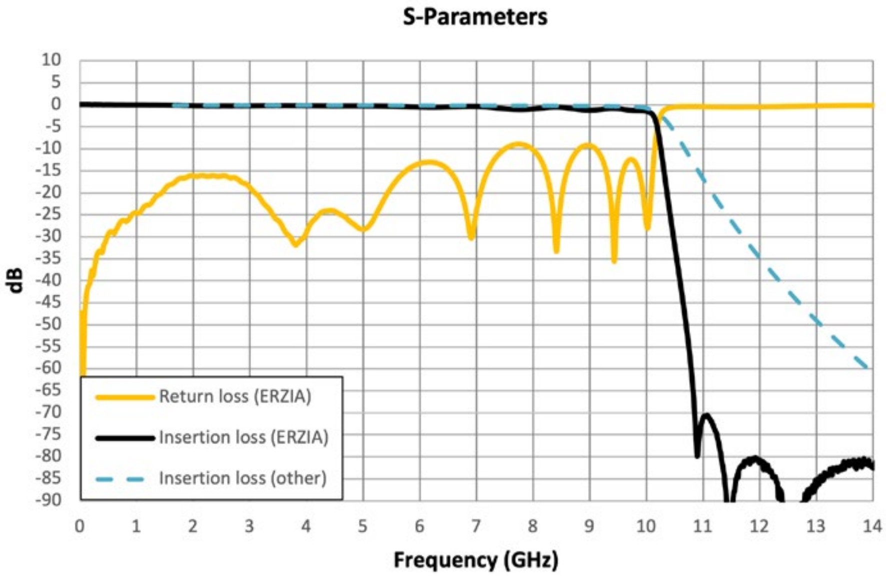
The first example is ERZ-LPF-0000-0100-1.5 shown in **Figure 4**.

Figure 4: *ERZ-LPF-0000-1000-1.5 wideband SSS filter*



The performance of this lowpass filter is shown in **Figure 5**.

Figure 5: *ERZ-LPF-0000-1000-1.5 filter performance. The performance of an alternative filter has been superimposed for illustration*



As can be observed, the filter features low insertion loss together with high selectivity (70 dB rejection at 0.85 GHz above the cut-off frequency). The 70-dB minimum rejection level is maintained along the stopband (from 11 to 14 GHz). The closest filter found in the market (not SSS) is based on tubular (coaxial) technology (blue dashed line in Figure 5). Both feature a same cut-off frequency and comparable return loss (RL). The alternative features a slight advantage on insertion loss (IL) and has a more compact size, although the length is similar. However, the SSS filter features an unbeatable selectivity with a sharp band edge showing 50-dB rejection at just 0.7 GHz above the cut-off frequency. A comparison can be found in the next table.

P/N	Technology	VSWR typ	Fc (GHz)	IL @ 9 GHz (dB)	Rejection level of 50 dB (GHz)	Dimensions (mm)
ERZ-LPF-0000-0100-1.5	SSS	10	1.58:1	<1.25	10.7	55 x 40 x 10
Other	Tubular	10	1.5:1	<1.0	13.1	6.35 x 6.35 x 48

Table 1: *Comparison of ERZ-LPF-0000-1000-1.5 with alternative filter*

Lowpass filter from 0 to 18 GHz

The second example of a wideband filter is shown in **Figure 6.**

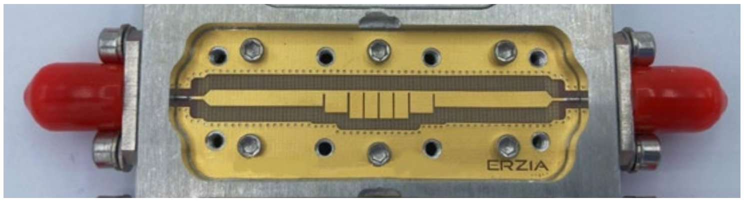


Figure 6: *ERZ-LPF-0000-1800-2.4 wideband SSS filter*

The performance of this lowpass filter is shown in **Figure 7.**

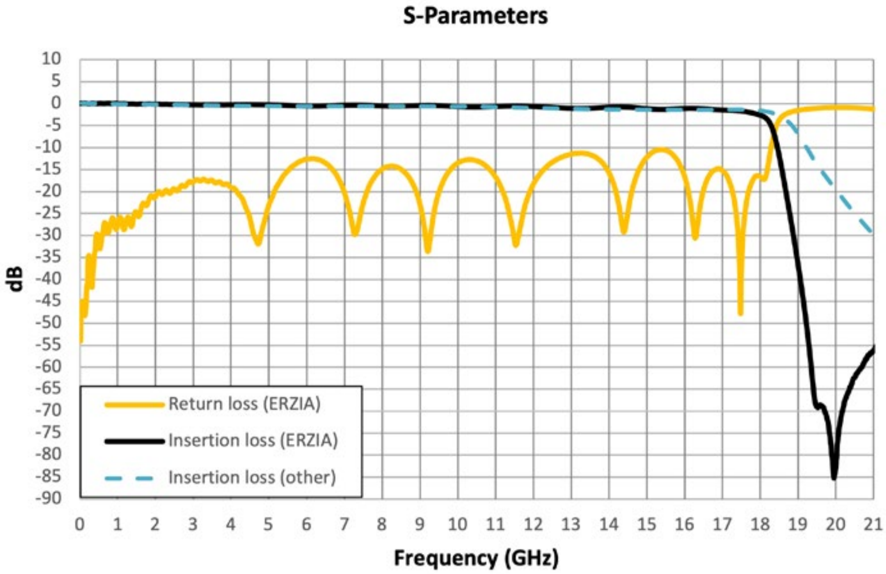


Figure 7: *ERZ-LPF-0000-1800-2.4 filter performance. The performance of an alternative filter has been superimposed for illustration*

In this case, both low insertion and return loss can be observed. One can observe a sharp band edge in this example. The performance of a commercial planar filter with similar cut-off frequency is included in **Figure 7** for illustration (blue dashed line). Both feature a similar size.

A comparison can be found on the next table:

P/N	Technology	Fc (GHz)	Frequency at which a rejection level of 35 dB is met (GHz)
ERZ-LPF-0000-1800-2.4	SSS	18	18.95
Other	Other planar	18	22

Table 2: *Comparison of ERZ-LPF-0000-1800-2.4 with a commercial alternative*

Again, the selectivity of the SSS filter is a clear advantage.

Highpass filter from 17.5 to 41 GHz

A third example is ERZ-HPF-1750-4100-2.0. A picture of the filter is shown in **Figure 8.**

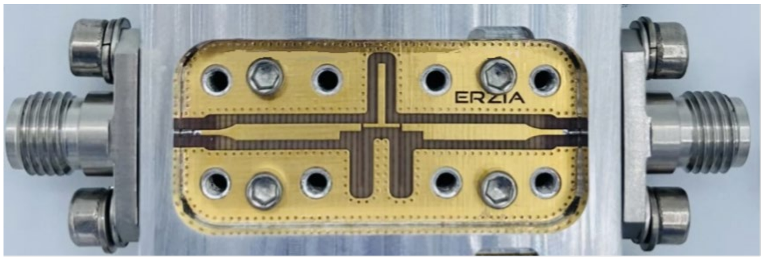


Figure 8: *ERZ-HPF-1750-4100-2.0 wideband SSS filter*

The performance of this highpass filter is shown in **Figure 9.**

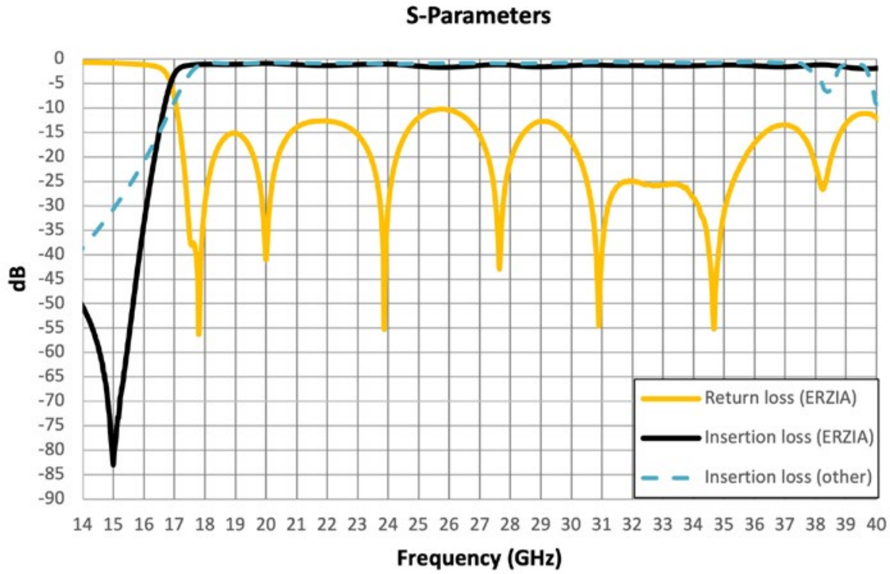


Figure 9: *ERZ-HPF-1750-4100-2.0 filter performance. The performance of an alternative filter has been superimposed for illustration*

In this case, the SSS filter obtains 34-dB rejection at 1.5 GHz below the cut-off frequency, while the alternative (cavity) takes another extra 1.5 GHz to meet this rejection level. It must be remarked that it was very hard to find a comparable filter for such a wide bandwidth, being the only result a cavity filter.

P/N	Technology	Fc (GHz)	Rejection level at f=Fc-1.5 GHz (dB)	Dimensions (mm)
ERZ-HPF-1750-4100-2.0	SSS	17.5	34	30 x 25 x 10
Other	Cavity	18	15	29.21 x 11.53 x 16.66

Table 3: *Comparison of HPF-1750-4100-2.0 with a commercial alternative*

Conclusions for wideband filters

Three wideband SSS filters have been compared with other alternatives. At low operation frequencies the filters show a similar performance and size, being the SSS filter clearly superior in selectivity. For higher operation frequencies up to 40 GHz, no waveguide counterparts were found, being a cavity filter the only alternative, but, again, the SSS filter features better selectivity.

Narrowband Filters

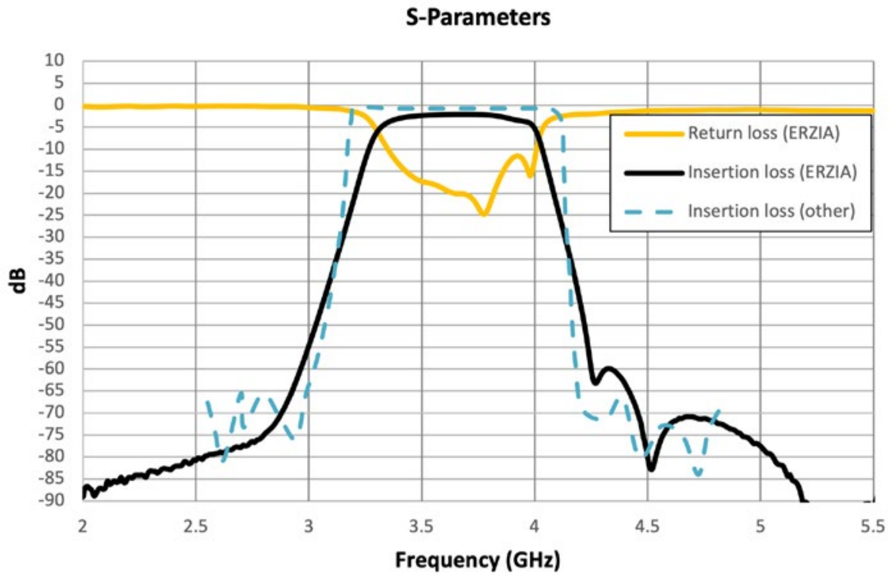
Two examples of narrowband SSS filters are presented next and compared with counter-parts implemented in other technologies. This time the frequency of operation is relatively low in contrast to the wideband filters presented in previous section, in order to explore the other extreme of the SSS range of operation.

Bandpass Filter from 3.5 to 3.8 GHz

The first example is a C-band bandpass filter (ERZ-BPF-0350-0380-2.4), centered at 3.65 GHz with a fractional bandwidth of 8.2%.

The performance of the filter is shown in **Figure 10.**

Figure 10: *ERZ-BPF-0350-0380-2.4 filter performance. The performance of a alternative filter has been superimposed for illustration (center frequency and bandwidth are normalized)*



The filter provides sharp band edges with exceptional selectivity. The closest alternative found is a waveguide filter (shown in dashed blue line in **Figure 10**). It is important to remark that the center frequency and passband have been normalized for comparison. Actual data of the alternative filter can be gathered from the following table.

P/N	Technology	F0 (GHz)	FBW (%)	Dimensions (mm)	Weight (g)
ERZ-BPF-0350-0380-2.4	SSS	3.65	8.2	90 x 40 x 10	120
Other	Waveguide	3.8	21	69.9 x 98.4 x 100	500

Table 4: *Comparison of ERZ-BPF-0350-0380-2.4 with a commercial alternative*

In this case, the waveguide filter gives better response in terms of selectivity but at the expense of a much bigger size and weight.

Bandpass filter from 1.9 to 2.1 GHz

The second example is an L-Band filter. The performance of the filter is shown in **Figure 12.**

Figure 11: *ERZ-BPF-0190-0210-1.8 bandpass SSS filter*

The response is shown following figure.

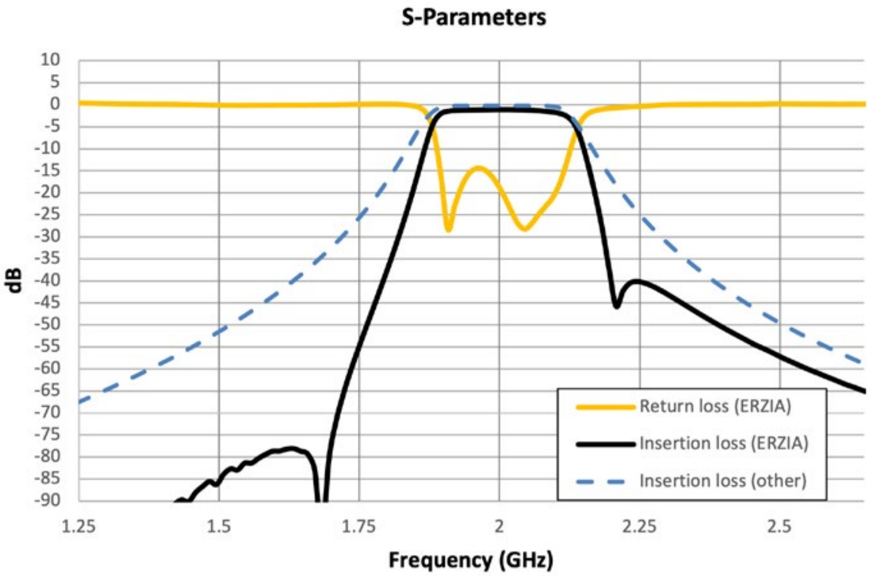


Figure 12: *ERZ-BPF-0190-0210-1.8 filter performance. The performance of alternative filter has been superimposed for illustration*

In this case, the alternative is a cavity filter (with a performance shown in dashed blue line in **Figure 12**), which features slightly better insertion loss but worse selectivity. Both options have a similar size.

P/N	Technology	F0 (GHz)	FBW (%)	Dimensions (mm)	Rejection level at 1.8 GHz (dB)	Rejection level at 2.2 GHz (dB)
ERZ-BPF-0190-0210-1.8	SSS	2	10	50 x 65 x 10	34	45
Other	Cavity	2	12.5	59.32 x 56.27 x 15.06	17	17

Table 5: *Comparison of ERZ-BPF-0190-0210-1.8 with an alternative filter*

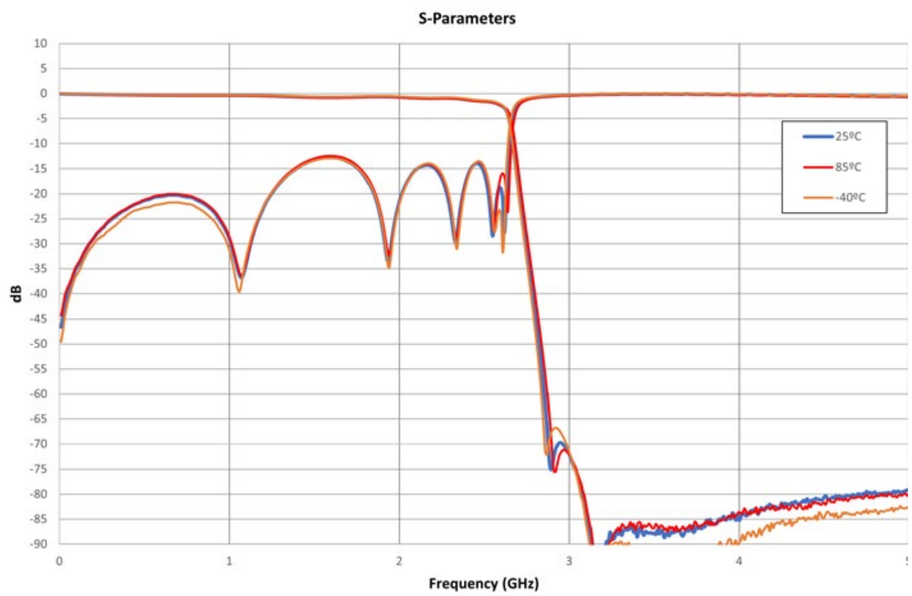
Conclusions for narrow-band filters

Two narrowband SSS filters have been compared with other alternative counterparts. A similar selectivity is obtained but at a much smaller size, as compared to the waveguide alternative. The SSS filter features higher selectivity at a similar size, as compared to the cavity alternative.

Performance of SSS filters over temperature

Temperature stability is crucial for reliable units which might be used in extreme environments or heavy duty applications such as RADAR, EW, Telecomunications, etc. In this section, the performance of a lowpass filter from 0 to 2.5 GHz (ERZ-BPF-0000-0250-1.3) over temperature is presented. **Figure 13** shows measurement results for this filter at +25°C, +85°C and -40°C.

__Figure 13:__ ERZ-BPF-0000-0250-1.3 filter performance over temperature



As can be gathered from **Figure 13**, there is no significant variation in the performance at the extreme temperature values. A small frequency shift can be observed: +10 MHz at +85°C and -20 MHz at -40°C. This example shows the thermal stability of SSS designs and can be extrapolated to all the examples presented before.

The temperature variation of alternative technologies is very wide and technology dependent.

Conclusion

A general description of SSS microwave filters has been presented. The main advantages and features have been discussed. Five different SSS filters have been compared to alternative filters based on different technologies.

Based on the previous comparative it has been observed that for wide frequency bands SSS filters offer unbeatable selectivity while maintaining similar size and insertion loss as compared to cavity and coaxial alternatives. When going higher in frequency, other wideband alternatives are found but with less selectivity.

Narrowband SSS filters are a good option in terms of insertion loss and selectivity when compared with cavity filters, but waveguide filters are still slightly better at the expense of a significant increment of size.

In the following, a table showing the best option in terms of size, selectivity and insertion loss for the five filters is included. The word “similar” is used when there is no significant difference between both options.

Compared Filters	Size	Selectivity	Insertion Loss
Wideband 0 – 10 GHz (SSS vs Coaxial)	Coaxial	SSS	Similar
Wideband 0 – 18 GHz (SSS vs Cavity)	Similar	SSS	Similar
Wideband 17.5 – 41 GHz (SSS vs planar)	Similar	SSS	Similar
Narrow-band 3.5 – 3.8 GHz (SSS vs Waveguide)	SSS	Waveguide	Waveguide
Narrow-band 1.9 – 2.1 GHz (SSS vs Cavity)	Similar	SSS	Similar

Table 6: *Summary of comparations*

Other characteristics like power handling or comparative temperature stability responses have not been evaluated in detail and might be the subject of another work. At any case, the excellent temperature performance of a SSS filter has been presented, being more stable than most of alternatives. The power handling of SSS filters presented are in the range of 10-15 W CW.

NEXT STEPS

The datasheets of the filters used in this paper are:

- ERZ-LPF-0000-1000-1.5
- ERZ-LPF-0000-1800-2.4
- ERZ-HPF-1750-4100-2
- ERZ-BPF-0350-0380-2.4
- ERZ-BPF-0190-0210-1.8
- ERZ-LPF-0000-0250-1.3

ERZIA catalogue of filters

SUSPENDED SUBSTRATE RF/MICROWAVE FILTERS | Erzia

ERZIA is under constant review of the state of the art to design new reliable and performant amplifiers. If you do not find what you are looking for at the catalogue, please ask us at sales@erzia.com.

For more information about the basis of SSS filters, check the bibliography below.

BIBLIOGRAPHY

[1] Suspended substrate stripline filters for ESM applications, J.E. Dean, IEE Proceedings F (Communications, Radar and Signal Processing), Volume 132, Issue 4, July 1985, p. 257 – 266, DOI: 10.1049/ip-f-1.1985.0059 , Print ISSN 0143-7070, Online ISSN 2053-7956.

[2] Design of generalised Chebyshev suspended substrate stripline filters, N. Lioutas, April 1986