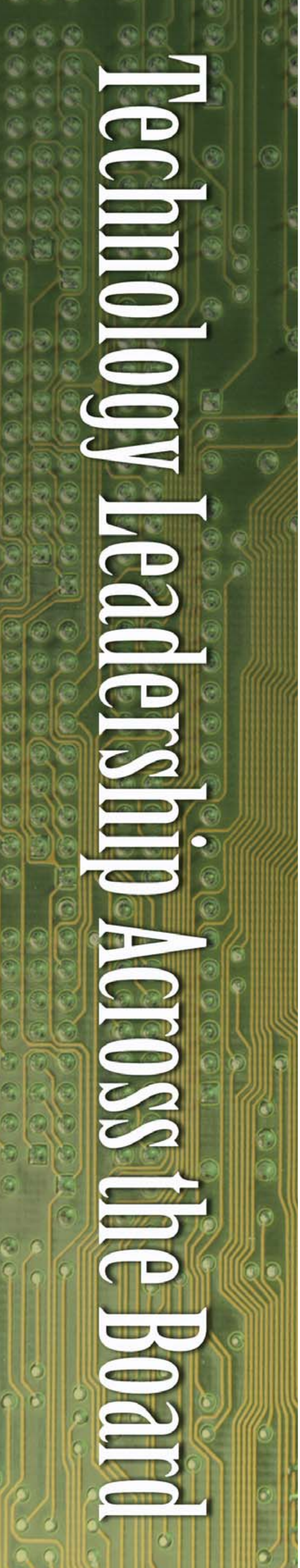

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Thin Film Filter Design and Technology

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Abstract

When specifying filter for a design, the admissible insertion loss and frequency range in the pass-band, the required attenuation and frequency ranges in the forbidden-bands, are the most important characteristics of filters. Several other important parameters are also required to define a filter, including functional parameters as input output impedances, power handling capabilities, and reliability requirements, as well as physical requirements such as dimensions, input-output type (wire-bond, SMT, BGA), and encapsulation. Other conditions may be imposed by special applications (space, automotive, medical). Some of the data needed to design a band-pass filter are illustrated in fig. 1.

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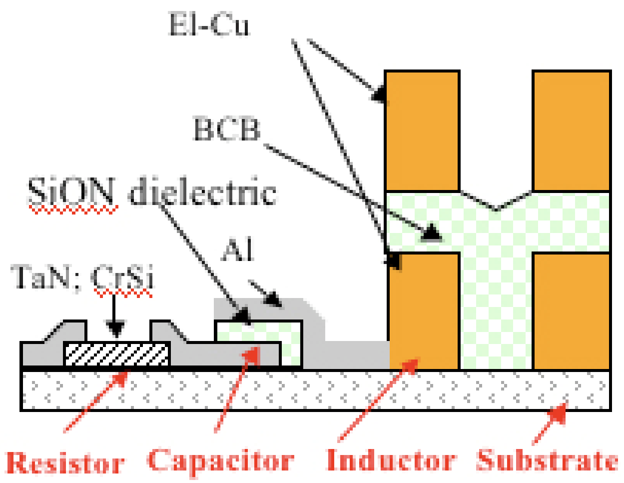


Fig. 1

Thin film technology is based mainly on vacuum processes (sputtering, CVD, evaporation) and for thicker conductive metal layers (Cu, Au, Ni) on electro-deposition. The structure is etched (subtractive process) or plated (additive process) using photolithography. The main advantage of thin film filters is its ability to achieve high accuracy in processing in small device sizes when compared it to competing technologies.

There are two main forms of thin film filters, lumped element (LE) design and distributed (D) design. As a general rule the LE design is suitable in the frequency range 500MHz to 5GHz and the D design in the frequency range 1GHz to 100GHz or higher. In the case of LE design the filter is composed of discrete inductors and capacitors where the size of the components is less than the wavelength at the highest critical frequency. The D design by definition has bigger dimensions than the largest wavelength of interest. The layer structure of the LE design, that is a version of the integrated passive devices (IPDs), is shown in Fig. 2. The IPDs are built on glass, quartz or Si substrates. The D design usually is build on alumina substrates with Cu or Au conductors having a strip-line or coplanar wave-guide structure.

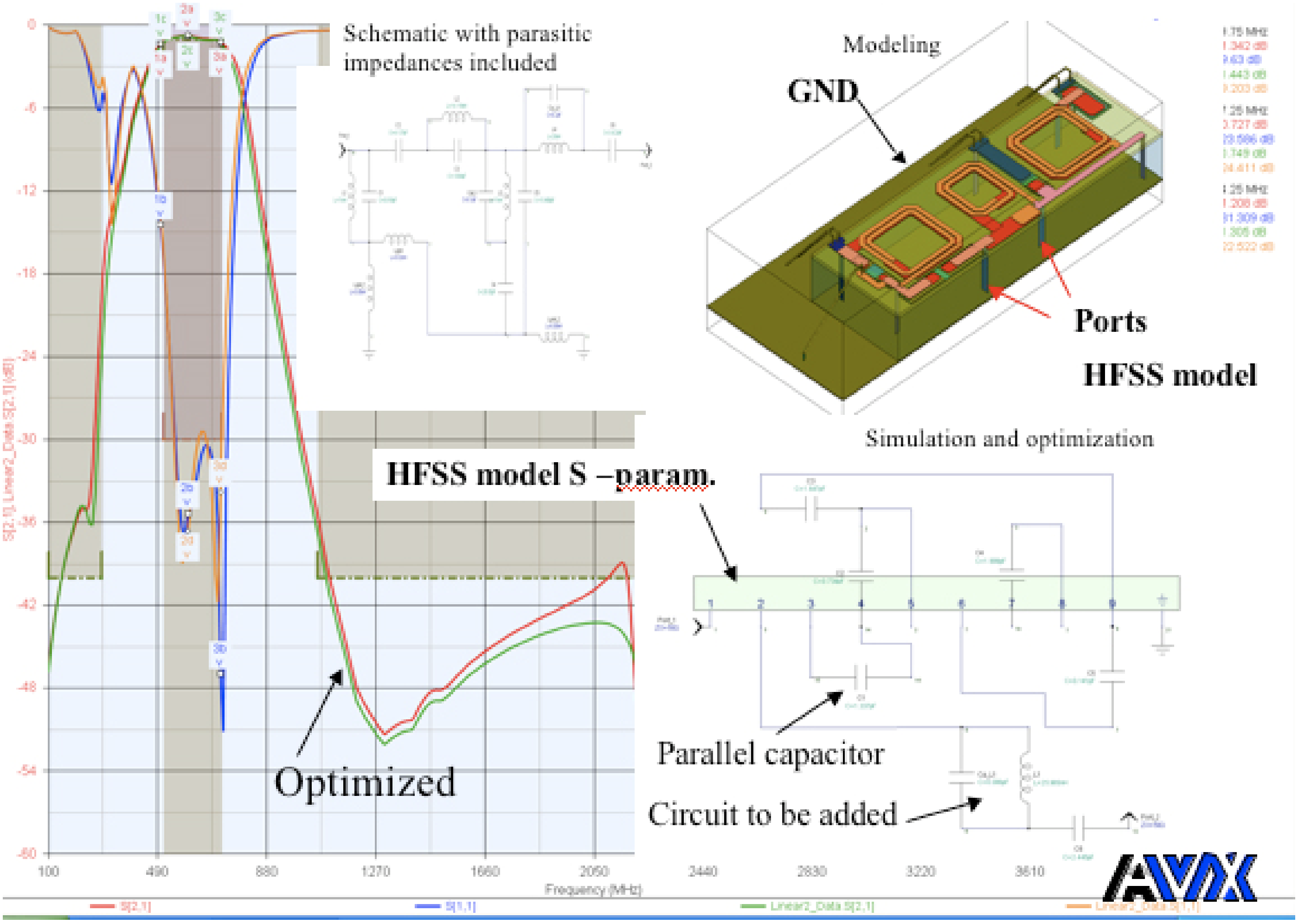


Fig. 2

The design methodology of the LE filters is illustrated in Fig. 3. Starting from the specification an equivalent circuit is generated adding to the usual L and C components estimated parasitic impedances as ESR and ESL. Then part of the filter is modeled in finite element software. The S parameters extracted are replacing the modeled components in the equivalent circuit. In the initial circuit not all the parasitic impedances were included, and definitively not with the exact values. To compensate for the errors due the approximations, ports are added to the model. The tunable capacitors across those ports and the components not included in the model allow for eliminating the effect of the parasitic impedances during the optimization step. The procedure is repeated until the design is complete.

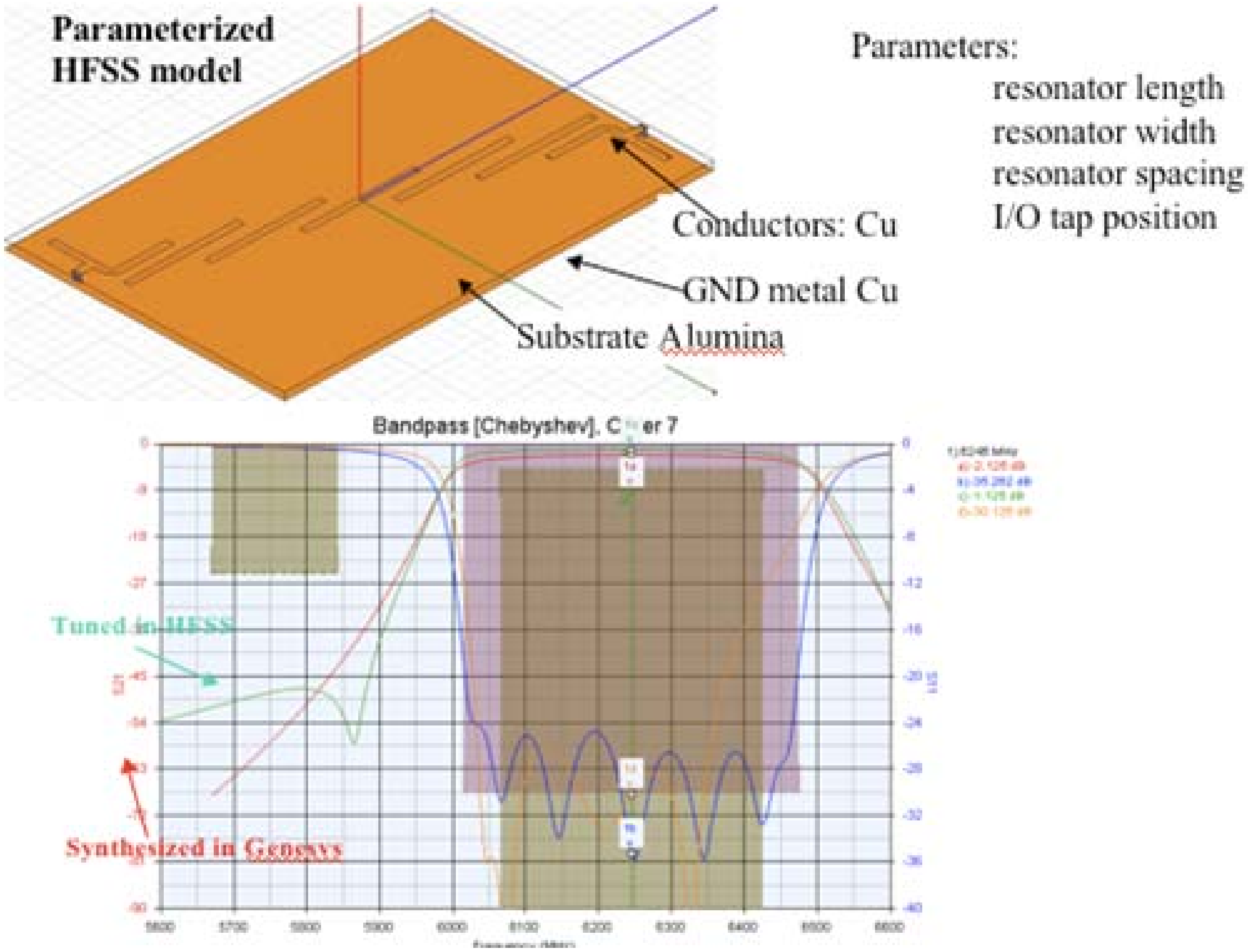


Fig. 3

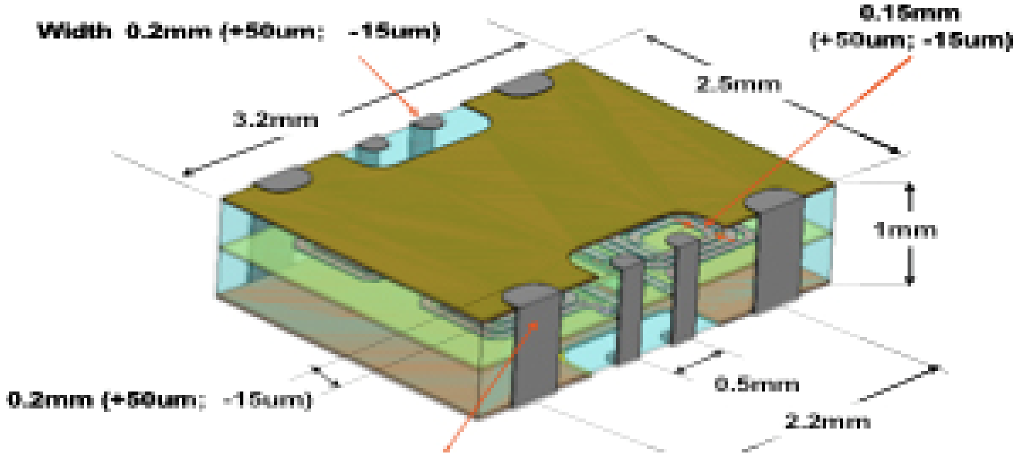
There are a large number of analytical methods to synthesize filters. The advance of computer technology did simplify this task considerably. Filter synthesis packages are available on a multitude of simulators; those simulators usually export also a layout file for the filter. This layout is imported in a finite-element modeling tool parameterized and optimized for the required performance as shown in Fig. 3.

One important point of concern is the electromagnetic environment around the filter during its use. As example, for the LE filters metallic planes can couple to the inductors reducing their inductance and degrading the quality factor (Q). As long as the position and the nature of those planes are known, established and respected, they will be included in the finite-element model and the predicted performance. This fact puts some limitation on the termination strategy. As a general precaution, SMT or wire-bond terminations are recommended. The “flip-chip” BGA termination will introduce distance variability to the metallic planes in the board due to the uncontrollable “ ball-collapse” during the reflow process.

An SMT type filter design is shown in Fig. 4. This is a perfectly symmetrical design, the two glass substrates having 0.5mm thickness, makes the distance to any metal layer in the board large enough to avoid change in the filter performance, for this particular case.

Fig. 4

DESCRIPTION: The filter is comprised of a thin film LC structure sandwiched between 2 glass wafers terminated using AVX FLEXITERM (conductive epoxy) technology.



Thin film filters provide all the advantages of thin film technology including high power handling, high stability and low noise. The use of thin film filters are becoming more accepted in the design community due to its ability to achieve high processing accuracy in small device at high frequencies. New technologies allow for a variety of terminations like SMT, wire-bond, BGA and LGA depending on the solution chosen for a given problem. In addition, thin-film technology can integrate the usual LC or transmission-line type structures with resistors (as example 50 Ohm termination) or create modules with active components attached.