PLANAR FILTERS AND MULTIPLEXERS

INSTRUCTOR

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TECHNOLOGY FOCUS

Planar filters are one of the fundamental building blocks used in integrated microwave assemblies, along with amplifiers, oscillators, mixers and switches. Depending on the frequency range and bandwidth we might use printed distributed filters, printed pseudo lumped filters, chip and wire lumped element filters and in some cases, cavity combline filters. Switched filter banks are common and sophisticated multiplexers are used in some systems.

Many broadband microwave down converters and up converters are built using thin-film technology on ceramic substrates. The substrates are placed in a channelized housing which isolates the various signal paths from each other. The front end, band select filters may be as broad as octave bandwidth, while the IF filters are typically much narrower. Filters used to clean up harmonics in the LO chain may be narrower still. It the past decade there has been a trend to use more printed circuit board technology when possible and even use commercial off the shelf (COTS) parts in both commercial and military systems.

EM simulation is also an essential component of filter design commercial and military systems. Distributed filters in a cut-off waveguide channel excite, and couple to, evanescent modes in the channel. The net result is the measured bandwidth of the filter is radically different with the cover on and the cover off. If the channel dimensions change, the filter must be redesigned. A design procedure that incorporates EM simulation is needed to include all the filter layout details and the coupling of the filter layout to the waveguide channel.

COURSE CONTENT

This course is devoted to the fundamentals of practical planar filter design for RF and microwave systems. The core material is a universal procedure for narrow band filter design that can be applied to virtually any filter technology or topology. The procedure is rooted in Dishal’s method with powerful extensions that include the port tuning concept, equal ripple optimization techniques, and efficient EM simulation. All the techniques presented can be implemented using commercially available CAD tools.

Broader band filters generally require a synthesized starting point for our design. But once we have a reasonable starting point we apply the same port tuning techniques to rapidly fine tune the design. The key in both the narrow band and the broadband cases is to minimize the number of full EM solutions that we run. The port tunings we apply in our circuit simulator always indicate the direction and relative magnitude of the corrections that need to be made to the filter geometry.

Example filter designs that cover a broad range of applications will be presented with measured data and error analysis. The instructor will choose examples to develop based on the interests of the class. The course material is suitable for filter designers, designers of other components, systems engineers, and technical managers.

Day One

Introduction to Filter Design, Optimization, and Port Tuning

We will present the briefest possible introduction to basic filter design concepts. Starting with lowpass prototypes, we will touch on Chebyshev and elliptic prototypes and finding prototype element values. Next we will turn to a brief overview of the most common filter design techniques. Topics will include synthesis from an insertion or return loss function, the coupling matrix approach, and synthesis by optimization. The use of general purpose linear simulators for equal-ripple optimization will also be discussed. Finally, we will introduce the port tuning concept.

- Basic Filter Concepts
- Chebyshev and Elliptic Prototypes
- Synthesis From Insertion Loss Functions
- Coupling Matrix Approach
- Synthesis by Optimization
- Equal-ripple Optimization
- The Port Tuning Concept

Day Two

Narrow Band Filter Design and EM Simulation

Our approach to narrow band filter design starts with Dishal's method and moves a step beyond with port tuning of a full EM model. The port tuned model is a virtual prototype that can be diagnosed and optimized before any hardware is built. Modern TEM filters often employ cascade triplets and quads to realize transmission zeros in the stopband or flatten group delay in the passband. These filters can also be designed using our approach. At some point, practical procedures are needed to measure unloaded Q, external Q, and coupling coefficients. Systematic methods for tuning filters are also needed. All of these methods and procedures can be applied to actual hardware or to an EM simulation of the hardware.

- Narrow Band Filter Design
- Cross-Coupled Filters
- EM Filter Prototypes
- Unloaded Q
- External Q
- Coupling Coefficients
- Filter Tuning

Day Three

Designing Planar Filters

Filters in planar form can be built using several different topologies and technologies. Various single and multilayer ceramic and soft substrate (PCB) technologies are available to the filter designer. We will cover the more common distributed topologies including edge-coupled, hairpin, and interdigital. More recent coupled and cross-coupled loop topologies will also be presented. At lower microwave frequencies a pseudo-lumped approach using printed inductors and capacitors is more space efficient. Lowpass, elliptic lowpass, and bandpass filters using this approach will be presented. Strategies for efficient design and EM simulation will be discussed for all the topologies presented.

- Planar Filters
- Edge-coupled, Hairpin, and Interdigital
- Coupled and Cross-coupled Loops
- Pseudo-lumped Lowpass and Bandpass
- Strategies for Design and EM Simulation