COMPACT 900 MHZ HAIRPIN-LINE FILTERS USING HIGH DIELECTRIC CONSTANT MICROSTRIP LINE

PROTAP PRAMANICK

Department of Electrical Engineering
University of Saskatchewan
Saskatoon
Canada

ABSTRACT

Several miniature bandpass filters have been developed by accurate modelling of experimental and computer generated coupling data of hairpin-line microstrip line resonators on high-K (K=80 to 90) substrates. The materials are temperature stable and of high quality factor. The experimental results show some novelty of the design approach. The method is useful in realizing planar filters for cellular radio and global positioning systems, and superconducting microstrip filters.

SUMMARY

This work describes the design approach, construction and the experimental performance of microstrip line hairpin-line filters using high dielectric constant (K=80 to 90) temperature stable ceramic substrates. The research was undertaken to develop miniature bandpass filters with sharp selectivity and amenable to inexpensive printed circuit board technology for mass production.

Miniature bandpass filters are very important in mobile cellular radio and Global Positioning System (GPS) units. The important targets for this technology are superior performance, smaller size and lower cost. Until now ceramic block versions of coaxial line filters, in interdigital or combline form, have been in the market. Such filters are designed empirically and tuned after production using metal scrapers and ceramic grinders.

Planar versions of the above interdigital or combline filters can be more accurately designed. However, the filters need grounding of resonators by wrap around metallization of each filter unit, leading to higher production cost [1].

The hairpin-line filter layout, shown in Figure 1, offers the best tradeoff among size, performance and production cost. It is obviously larger than interdigital and combline filters, but it requires no grounding. Consequently, a large number of filters can be simultaneously printed on a single substrate board leading to lower production cost.

Recently Winter et al. [2] reported a stripline gap coupled resonator filter using moderately high-K (K=38) ceramic material. The filter has a substrate and a superstrate, and has been designed for operation at 6 GHz. Although the filter requires no grounding of resonators, the overall length of the filter is 30 millimetres. For our application, we are looking for an overall length of 52 millimetres for operation at around 1 GHz. Keeping all these factors in mind we chose microstrip line hairpin-line resonators with small interarm spacings.

Traditionally, the interarm spacings in hairpin-line filter design is kept large so that the coupling between the arms can be neglected [3]. Crystal's [4] unified design method takes the interarm coupling into consideration. However, it assumes negligible phase shift over the line joining the arms of a hairpin. Such is not the case when high-K medium is used. Moreover, Crystal's design equations are not applicable to inhomogeneous media.

Microstrip line, being inhomogeneous, is not amenable to Crystal's design method for hairpin-line filters. As a result, Dishal's [5] method has been adopted to obtain the interresonator coupling as a function of the spacing between resonators for a given set of substrate dielectric constant and height, microstrip width and frequency. However, unlike in reference [1] Dishal's method in this work has been implemented both theoretically and experimentally.

For theoretical evaluation of interresonator couplings, commercially available software packages like TOUCHSTONE [6] or SUPERCOMPACT [7] etc. could not be used because the models in those softwares are not valid for high dielectric constant media. Therefore the softwares, based on rigorous technique, like LINPAR [8] and MATPAR [9] were used in conjunction with the equivalent network parameters of the microstrip line discontinuities occurring in a hairpin-line resonator. Thus semiempirical design curves and equations have been formed from an aggregation of theoretical and experimental data, for different sets of microstrip parameters and frequencies.

Realization of hairpin-line filters using high-K materials poses another serious problem when 50 ohms input/output tapping lines are designed. Those line widths become unrealizably small. Therefore the tapping line impedance is made smaller than 50 ohms, as shown in Figure 1, so that the lines can be conveniently realized without any etching and tolerance problems. As a result, the input/output reference planes are shifted outwards, from the conventional 50 ohms tapping points, for connection to a 50 ohms system. These factors are taken into consideration when the loaded Q-factor is evaluated and modelled.

Figure 2 shows the overall package of the filters. Figure 3 shows the experimental results of a five pole filter centred at 905 MHz with 46 MHz bandwidth and 20 dB return loss. The substrate thickness and the dielectric constants are 2 milllimetres and 80 respectively. The substrate material is a solid solution of Barium and Strontium Titanates, and has a dielectric Q of 10,000.

Figure 4 shows the results of a five pole filter realized on Niobium-Niodinum Titanate substrate. The dielectric constant of the material is 90. The substrate thickness is 1 millimetre. The filter was designed for 16 dB return loss and a four percent bandwidth centred at 850 MHz. The measured results show a 0.4 percent shift in the center frequency. Results of few more open and shielded microstrip filters and the design informations are not presented here due to lack of space.

We would like to mention that the possibility of combining this research with high temperature coefficient superconductors looks very promising because superconducting microstrip lines are realized on high-K (K=25) substrate. In addition, using K=80 to 90 for microstrip line hairpin-line filter is the first such application.

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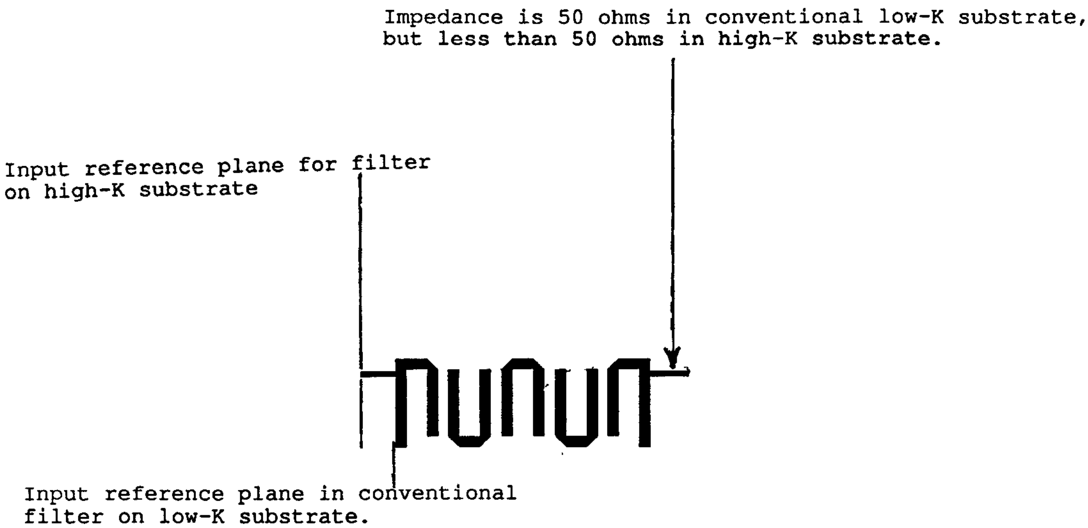

Figure 1. Microstrip line hairpin-line filter layout.

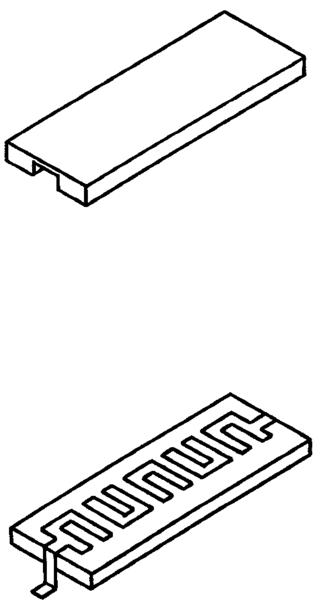

Figure 2. The hairpin-line filter package.

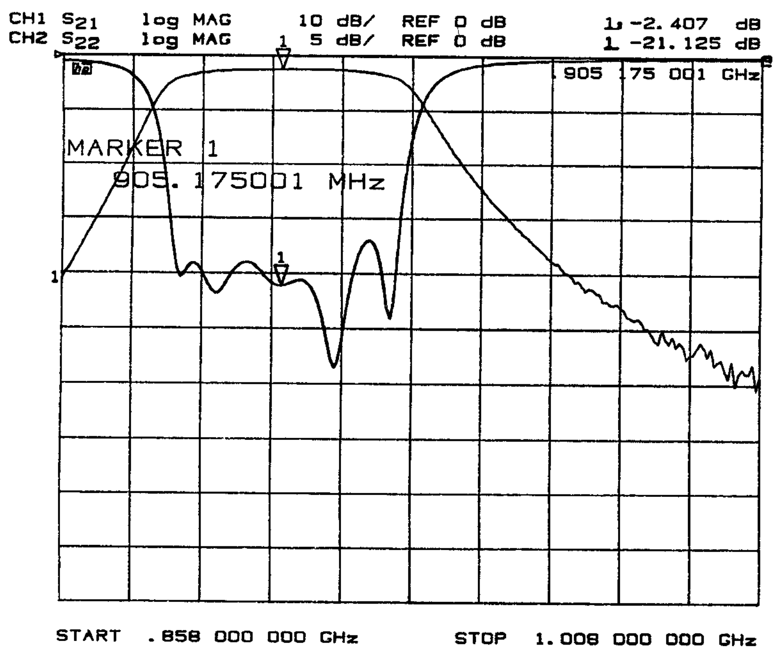

Figure 3. Measured response of five pole Chebychev filter on 2 mm thick substrate (K=80)

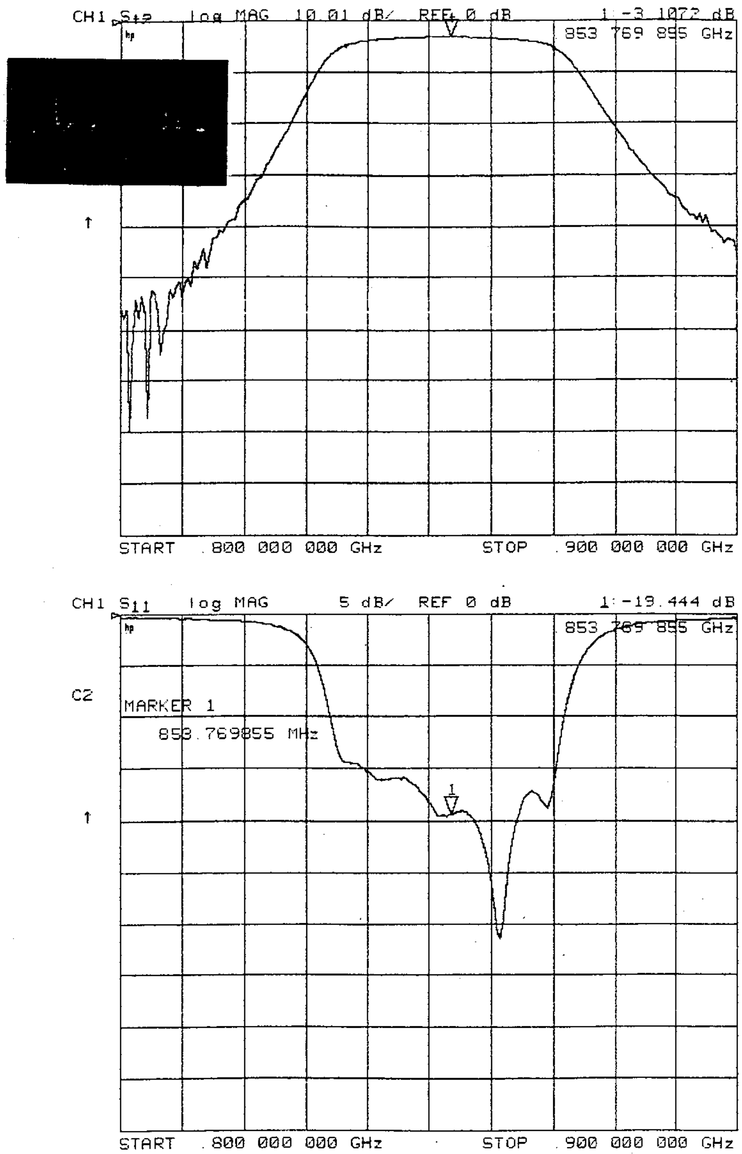

Figure 4. Measured response of five pole Chebychev filter on 1 mm thick substrate (K=90)