# A PRACTICAL TRIPLE-MODE MONOBLOCK BANDPASS FILTER FOR BASE STATION APPLICATIONS

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## ABSTRACT

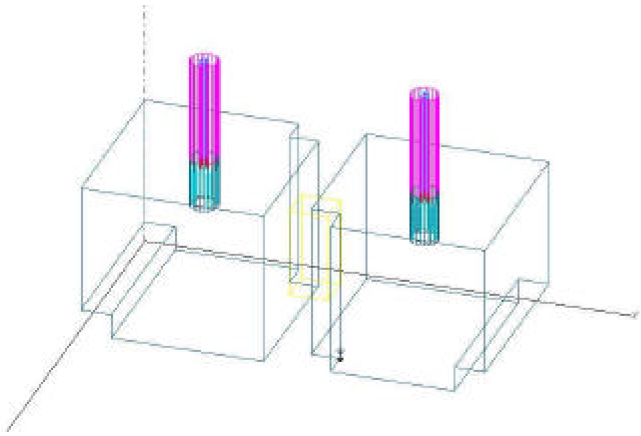
A practical triple-mode dielectric mono-block band pass filter integrated with a wide bandwidth pre-select mask band pass filter and a microstrip low pass filter for WCDMA base station application is presented. The dielectric mono-block triple-mode filter was designed and optimized using 3D EM simulation software incorporating the equivalent circuit model. The pre-select filter and low pass filter were used to clean up the spurious response of the triple-mode filter up to 12 GHz. Both triple mode and mask filters are directly mounted on the PCB to minimize the cost and loss.

## I. INTRODUCTION

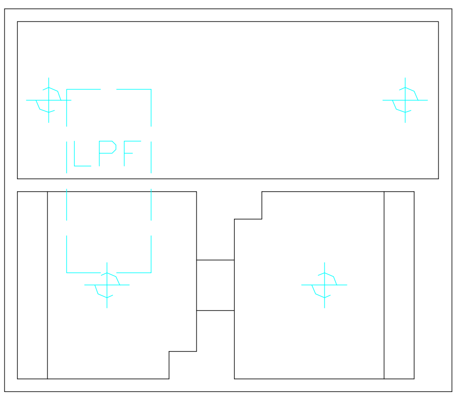
Passive microwave filters occupy a significant portion of total space of the mobile base stations and usually determine the performance of the RF systems. Tremendous progress on miniaturization of the cavity resonators and band pass filters has been achieved since 1960's. The use of multi-mode resonators to realize band pass can significantly reduce the size of the band pass filters and provides the nonadjacent coupling easily to realize elliptic function frequency responses of the filters [1]-[8]. Dielectric and dielectric loaded resonators using low loss high dielectric constant materials can scale down the size of the resonator to as much as the square root of the dielectric constant, which results in a significant reduction on size and achieving high quality factor, low loss performance at the same time [2]. However, for both multi-mode and dielectric resonators, a well-known drawback, which usually prevents them from being used in the applications, is their inferior spurious characteristics.

On the other hand, tremendous progress has been achieved and extensive research has been performed on mono-block TEM mode dielectric filter, SAW filter, multi-layer LTCC filter and MEMS filter for receive and handset applications. These highly integrated filters offer an alternate approach of filter miniaturization with trade off of size, cost and performance. On-board surface mount passive components allow higher-level integration of RF systems in the development of wireless communication systems. Considerable potential of saving the volume and cost of the RF systems of base stations exists through the integration of RF filters.

In this paper, a practical highly integrated triple-mode dielectric mono-block band pass filter package for WCDMA base station application is presented. The dielectric triple-mode filter including the input/output coupling with minimum tuning effort was designed and optimized successfully using 3D EM simulation software incorporating the equivalent circuit model. A wide bandwidth cavity pre-select mask band pass filter and a microstrip low pass filter integrated into circuit board were used to clean up the spurious frequency response of the filter up to 12 GHz. Both ceramic triple mode filter and pre-select mask filter are designed to be able to be directly mounted on the PCB to minimize the cost and loss of the filter.



( a )




( b )

Fig. 1 ( a ) Configuration of the triple-mode dielectric mono-block filter; ( b ) Top view of the proposed dielectric mono-block triple-mode filter assembly.

## II. CONFIGURATION AND ANALYSIS

Fig. 1 presents the proposed triple-mode dielectric mono-block band pass filter and its integrated assembly. A 6-pole dielectric mono-block triple-mode filter achieves required pass band performance and stop band roll off. A wide band pre-select combline filter with small footprint is used to achieve the required rejection up to 5 GHz, while a microstrip line low pass filter with transmission zeros will clean up the spurious response to 12 GHz. Both ceramic triple mode filter and pre-select mask filter will be directly mounted on the PCB. The microstrip low pass filter is integrated into the circuit board. The overall dimension of the filter assembly at 2.0 GHz is about 2.0”(L) x 1.6”(W) x 1.20”(H).

The design of the triple-mode filter has been performed using the 3D finite element method EM simulation software. The dimension of the single triple-mode cavity was first optimized using both 3D simulation software and circuit model network theory, combining the optimization techniques. Adjusting the dimensions of the each side of the cavity and the corner cuts for coupling M12, and M23 to the desired resonant frequency and coupling values.

Having determined the initial dimensions of the triple mode cavity and the corner coupling cuts, the second triple mode cavity, which is identical to the first one, can be brought into the full-wave simulation. Due to the significant interaction among the triple mode resonators and the aperture coupling to the resonant frequency of the resonators and the couplings and the efficiency of the 3D software, direct optimizing the filter dimension becomes almost impossible. Instead, circuit modeling and optimization techniques are used to determine the coupling matrix of the triple mode filter based on the frequency responses of the triple mode filter from 3D simulation results. By optimizing the coupling matrix of the filter to match the simulated frequency response, the resonant frequencies and couplings of the triple mode filter can be obtained. Comparing the results with the designed value and using the simulated design curved, the new filter dimensions closer to the final design can be determined.

The low pass filter will form part of the microstrip circuit that connects the triple-mode and mask filter elements. Radial stubs, rather than rectangular stubs, are used in order to avoid the excitation of higher order modes and, thereby, achieve the desired broadband operation. The radial stubs also allow for a more precisely defined location, as compared to rectangular stubs, which becomes more important for the higher frequencies specified for this design [9]. The overall size of 1.7 cm by about 0.6 cm is small enough to fit easily on the bottom of printed circuit board that holds the triple-mode filter and the mask filter.

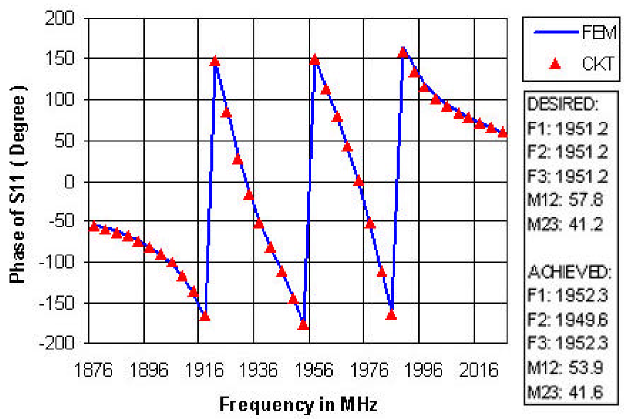



Fig. 2 Matched circuit model S11 phase response of a single triple mode cavity to the 3D FEM simulation results.

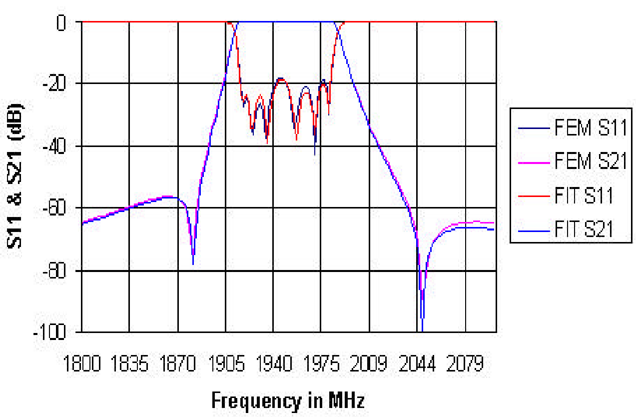



Fig. 3 Simulated frequency responses and the curve-fitting network's frequency responses of the filter by simulation.

## III. RESULTS

Based on previous analysis, the complete filter package, including a 6-pole triple-mode filter, a 4-pole mask filter and a 5-stage microstrip low pass filter, has been designed. Fig. 2 shows the matched circuit model S11 phase responses of the single triple mode cavity to the 3D FEM simulation results so that all the resonant frequencies and couplings can be obtained. Both narrow band and wide band frequency responses of the filter have been obtained including all the interaction of the resonators and higher order mode effects.

Fig. 3 presents the simulated frequency responses and the curve fitted circuit network's responses of the filter by optimization. It is seen that the filter's response has slightly dispersion on the rejection of the stop band due to the unwanted nonadjacent coupling M13, and M46. Fig. 4 shows the simulated wide band frequency response of the design filter using HFSS 3D software.

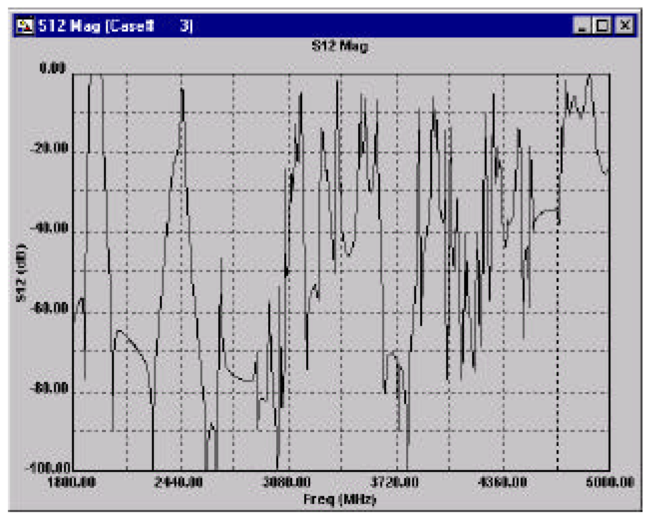



Fig. 4 Simulated wide band frequency response of the design filter using HFSS 3D software.

Fig. 5 shows the measured frequency responses of the mask filter before silver plating. The mask filter achieves the required bandwidth, return loss and stop band rejection. Figure 6 shows the microstrip filter designed for this purpose, and the simulated frequency response.

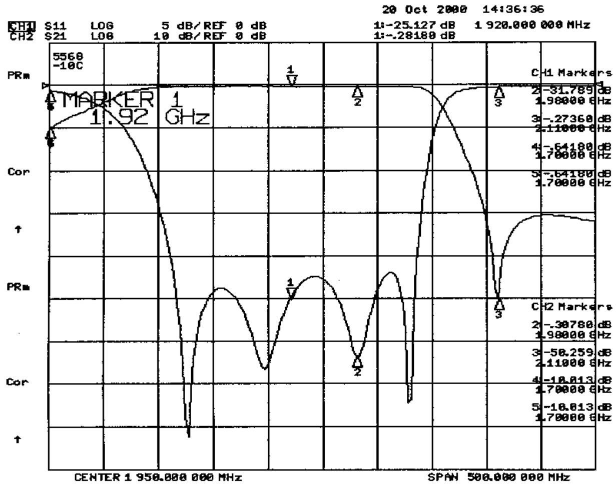



Fig. 5 Measured frequency responses of the pre-select mask filter.

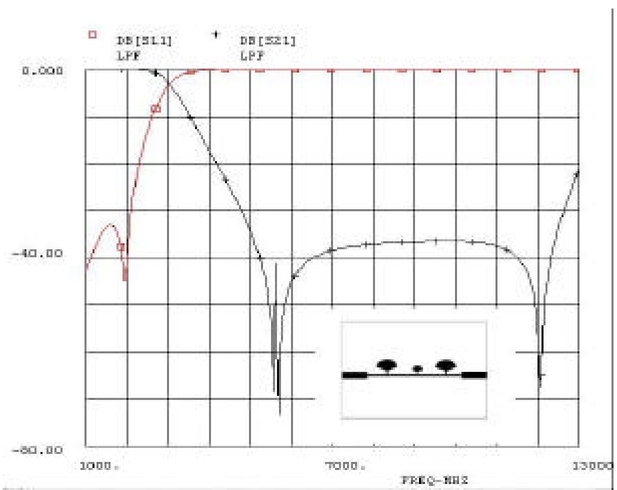



Fig. 6 Simulated frequency response of the microstrip low pass filter.

## CONCLUSIONS

A practical triple-mode dielectric mono-block band pass filter package, including a triple-mode filter, a pre-select filter and a microstrip low pass filter, for WCDMA base station application is presented. The triple-mode filter including the input/output coupling was designed and optimized successfully using 3D EM simulation software incorporating the equivalent circuit model. The wide band mask band pass filter and microstrip low pass filter achieve extremely wide spurious free response. The overall filter assembly has high performance with very small size, and shows to be a promising new type of filters for future base station applications.

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