# PWW Bandpass Filter for 60 GHz Band Based on 2D MoM Design Optimization

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*Abstract* - **In this paper, a bandpass filter (BPF) at 60 GHz band based on new design procedure is presented. The BPF is constructed by quartz-based post-wall waveguide (PWW) due to its lower dielectric loss. Filter design is achieved by optimization theory and burden for design is reduced by modeling filter as two dimensional structure. The 2D model is analyzed by using the method of moment (MoM) with global basis function. Validity is shown by a reasonable agreement between S-parameters for 2D model and those for 3D model.**

*Index Terms* — **Bandpass filter, 60 GHz band, PWW, MoM**

## 1. Introduction

Recently, a special attention is given to 60 GHz band radio application by a demand for high speed and huge capacity wireless network. 60 GHz band possesses advantages in unlicensed bandwidth at 60 GHz band up to 9 GHz [1]-[2]. For applying 60 GHz band to such wireless communication, millimeter-wave circuits are required to have low loss, low cost fabrication and broadband operation. Additionally, integration of circuits with other devices such as antenna is also needed by a so called antenna-in-package method.

In this paper, a design for bandpass filter (BPF) at 60 GHz band is presented. The BPF is constructed by post-wall waveguide (PWW) on quartz substrate which has lower dielectric loss [3]. Generally, the BPF is designed based on the cascaded impedance inverters as described in [4]. By using this design method, there is difference in frequency characteristics between filter on cascaded inverters and optimized one. It is cumbersome and time-consuming to optimize the filter even though circuit parameters for filter design are identified. In this investigation, for design efficiency, PWW BPF is designed as two dimensional model and optimized theory are employed. The 2D model is analyzed by using the moment method (MoM) with global basis function [5]. A comparison between 2D model and 3D model is done and a PWW-BPF with microstrip line (MSL) transition is also analyzed and compared. Reasonable agreement is obtained between them.

## 2. Formulation

Based on the reference [5], PWW is modeled as conductive circular cylinder in dielectric media whose height is infinity as shown in Fig. 1. In this assumption, scattered field with $TE_{10}$ mode incidence can be expressed as:

$$E_z^s(\vec{\rho}) = -\frac{k_0 Z_0}{4}\oint H_0^{(2)}(k_0|\vec{\rho}-\vec{\rho}'|)J_z(\vec{\rho}')d\vec{\rho}' \quad (1)$$

where $k_0$ is a wavenumber and $Z_0$ is intrinsic impedance in free space. $H_0^{(2)}$ is the Hankel function of the second kind of 0-th order. Vectors ρ and ρ' denote observation point and source point. As the filter characteristics are evaluated by using frequency response of plane wave excitation, an incident electric field is described by:

$$E_z^{inc} = e^{-jk_0(x\cos\varphi_0 + y\sin\varphi_0)} \quad (2)$$

For obtaining scattered field by solving the integral equation (1) as the method of moment (MoM), current density is expanded with global basis function:

$$J_z(\vec{\rho}') = \sum_{n=-N}^{N} a_n e^{-jn\theta} \quad (3)$$

where $a_n$ is an unknown coefficient. The global basis function reduces calculation load due to its small number of coefficient with preciseness.

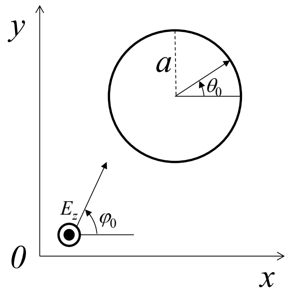


Fig. 1. Scattering problem for conductive circular cylinder.

## 3. Filter Structure and Design

Figure 2 shows the structure of PWW BPF. The BPF consists of a detection part for standing wave ratio (SWR) of electric field and filter part with iris as depicted in [6]. The SWR detection part observes reflected field from filter and its length is long enough to calculate reflectance precisely.

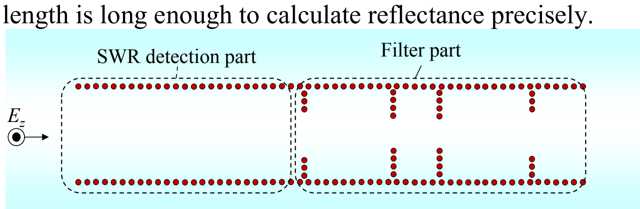


Fig. 2. Structure of proposed PWW-BPF.

To decide the dimension of the BPF for appropriate response of filter, genetic algorithm (GA) optimization is applied [8]. In the GA optimization to the PWW BPF, a crossover process is done by exchanging position of the iris between BPF individuals and a mutation process is carried out by slight change on position of the BPF. A fitness function is described by using a summation of reflectance and transmittance at pass and stop bands with weighted coefficients for the optimization. It is because specifications for reflection and transmission such as bandwidth and magnitude are different from each other.

## 4. Performance Evaluation

To show the validity of proposed design, 3D simulation model whose dimensions are optimized by 2D-MoM and GA is analyzed and compared with each other. In this design optimization, 3 dB bandwidth for $|S_{21}|$ and 10 dB bandwidth for $|S_{11}|$ are set to be 7 GHz from 57-64 GHz. The simulation is done by HFSS$^{TM}$. Figure 3 shows simulation model of PWW BPF. The GCPW-PWW transition used in [9] is connected to one of PWW BPF for measuring RF probe. The dimensions of GCPW and tapered MSL are also optimized for impedance matching to PWW.

Figure 4 shows S-parameters for BPF model by MoM and BPF by HFSS. The BPF of HFSS is modeled without GCPW-PWW transition. Good agreement is obtained in both $|S_{11}|$ and $|S_{21}|$ so that precision of the proposed 2D-MoM is demonstrated. Figure 5 also shows simulated S-parameters for HFSS models of with and without transition. Reasonable agreements in bandwidth and position of poles are obtained. An insertion loss at 60 GHz is 2.3 dB and 3 dB bandwidth is from 57.7-62 GHz in the BPF with transition. An increase of the insertion loss in the BPF with transition is due to propagation loss of the transitions and a decrease of bandwidth is due to the mismatch of impedance between the BPF and transition.

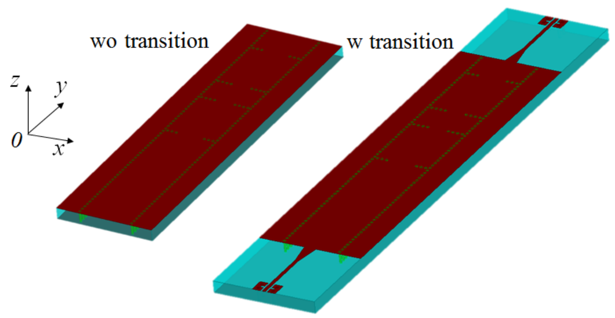


Fig. 3. Simulation model of PWW-BPFs with and without transition.

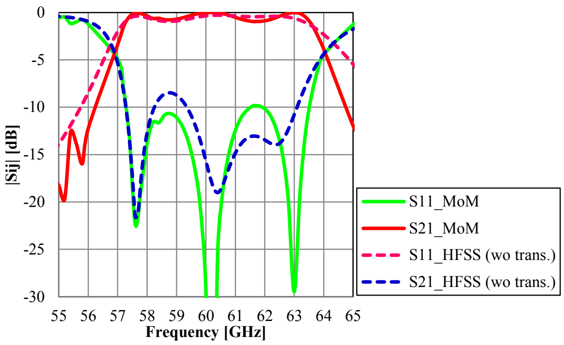


Fig. 4. S-parameters for simulation models of MoM and HFSS without transition.

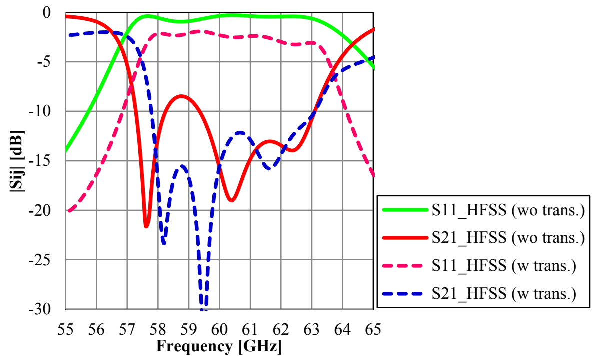


Fig. 5. S-parameters for HFSS models of with and without transition.

## 5. Conclusion

A post-wall waveguide based bandpass filter at 60 GHz band is designed by a new optimization procedure. A 2D model is applied and analyzed with the method of moment for the design optimization. The appropriate method is finally demonstrated by fairly good agreement on S-parameters between 2D- and 3D-models. Additionally, a filter model optimized by the proposed design procedure has been fabricated and measured.

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