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THREE-SECTION DUAL-BAND FILTER ON RECTANGULAR DIELECTRIC RESONATORS

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Трех-звенный двухполосный фильтр на прямоугольных диэлектрических резонаторах

В работе показана возможность построения трех-звенного двух-полосного фильтра на прямоугольных диэлектрических резонаторах, возбуждаемых на магнитных типах колебаний: $TE_{01\delta}$, $TE_{02\delta}$. Предагаемая структура проста в изготовлении и не использует дополнительных элементов настройки. Исследованы частотные зависимости матрицы рассеяния фильтра в обоих полосах пропускания.

Introduction.

In the past decade, the dual-band filters have been studied and designed widely for satellite applications rather than combining two individual filters into one common circuit resulting in more volume, mass, and, eventually, higher insertion losses since more elements are involved in the RF front-end [1]. Dual-band filters based on dielectric resonators (DR) are usually narrow-band with low in-band losses and good isolation between two bands [2].

In [3], a dual-band filter design based on two rectangular dielectric resonators has been studied. Apparently, the simultaneous tuning of two pass-bands has been achieved on the condition of equal alteration of coupling coefficients, provided by corresponding choice of the device design, DRs’ size as well as operating modes, namely magnetic $TE_{01\delta}$, $TE_{02\delta}$. In this paper, the possibility of dual-band filter synthesis consisting of three DR has been under research. The applied methods include the analytical one as well as Finite Element Method (FEM).

Main part.

The construction of dual-band band-pass filter consists of metal cavity with three rectangular DR of 4.26*4.26*9.33 mm size manufactured from material with $\varepsilon_r = 80, tg\delta = 5\cdot 10^{-4}$ as well as two oppositely directed metal pins, bound with coaxial lines (fig.1). The filter tuning, depicted in fig.1, has been conducted by providing numerical solution of boundary problem, namely by applying FEM realized in HFSS software. The amplitude-frequency response of the filter in each pass-band has been illustrated in fig.1,2.

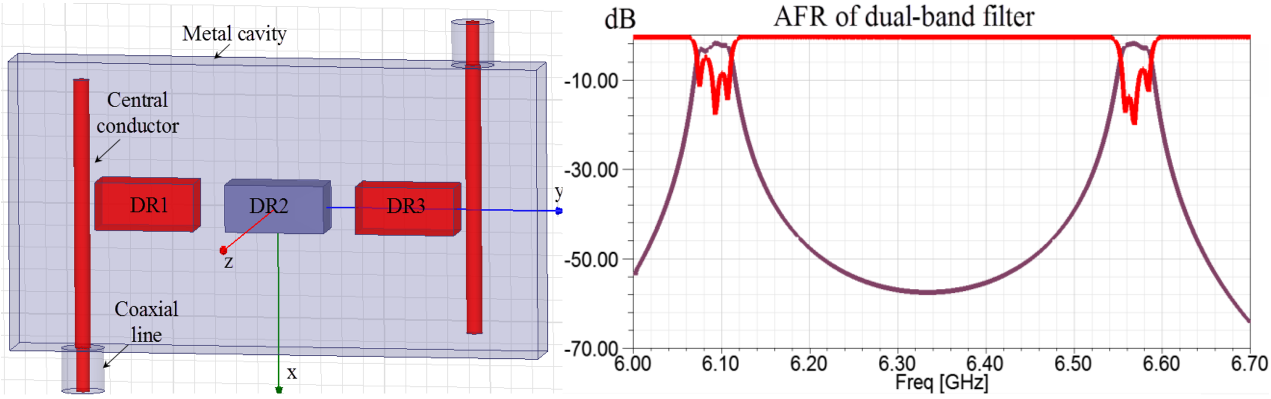

Fig. 1. Construction and AFR of the investigated dual-band filter on rectangular DR

Eventually, by addressing the scattering problem of electro-magnetic waves from a system of three coupled DR [4] the following analytical relations have been derived for transmission coefficient as well as reflection coefficient for the three-resonator dual-band band-pass filter:

$$T(f)=\sum_{j=1}^{2}\frac{-2*Q_D}{4k_{12\_j}*\lambda_{1\_j}-4k_{12\_j}*\lambda_{3\_j}}\left(\frac{2\tilde{k}_{11\_j}*k_{12\_j}*\lambda_{1\_j}}{Q_{1\_j}(f)}+\right.$$
$$\left.+\frac{2\tilde{k}_{11\_j}*k_{12\_j}*\lambda_{3\_j}-2\tilde{k}_{11\_j}*k_{12\_j}*\lambda_{1\_j}}{Q_{2\_j}(f)}-\frac{2\tilde{k}_{11\_j}*k_{12\_j}*\lambda_{3\_j}}{Q_{3\_j}(f)}\right),\qquad(1)$$
$$R(f)=1-\sum_{j=1}^{2}\frac{-2*Q_D}{4k_{12\_j}*\lambda_{1\_j}-4k_{12\_j}*\lambda_{3\_j}}\left(\frac{2k_{11\_j}*k_{12\_j}*\lambda_{1\_j}}{Q_{1\_j}(f)}+\right.$$
$$\left.+\frac{2k_{11\_j}*k_{12\_j}*\lambda_{1\_j}-2k_{11\_j}*k_{12\_j}*\lambda_{3\_j}}{Q_{2\_j}(f)}-\frac{2k_{11\_j}*k_{12\_j}*\lambda_{3\_j}}{Q_{3\_j}(f)}\right),$$

where Q_D - Q-factor of dielectric ,

$\tilde{k}_{11\_j}$ - coupling coefficient between the transmission line and DR in j-th operating mode,

k_{12_j}, k_{13_j} - are the cross-coupling coefficients between the first and second DR as well as first and third DR correspondingly in j-th operating mode.

f_{0_j} - the resonance frequency of j-th operating mode;

$\lambda_{1,3\_j}=0.5*\left(i*\tilde{k}_{11\_j}+k_{13\_j}\right)\pm 0.5*\sqrt{d}$, $\lambda_{2\_j}=i*\tilde{k}_{11\_j}-k_{13\_j}$,- j-th eigenvalue of the coupling operator, $d=\left(i*\tilde{k}_{11\_j}+k_{13\_j}\right)^2+8k_{12\_j}^2$,

i - imaginary unit;

$$Q_{1,2,3\_j}(f)=\frac{f}{f_{0\_j}}+2iQ_D\left(\frac{f}{f_{0\_j}}-1-\frac{\lambda_{1,2,3\_j}}{2}\right).$$

The coupling coefficients have been calculated for each band, namely:

$\tilde{k}_{11\_1}=2.67*10^{-3}, \tilde{k}_{11\_2}=2.75*10^{-3}, k_{12\_1}=4.41*10^{-3}, k_{12\_2}=3.25*10^{-3}, k_{13\_1}=0.037*10^{-3}$, $k_{13\_2}=5*10^{-7}$.

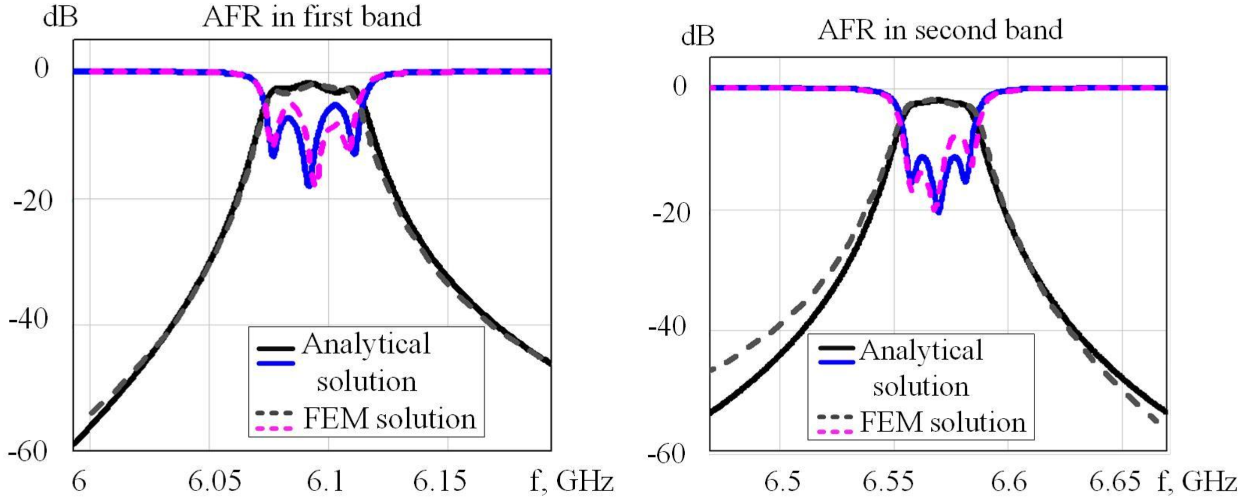

Fig.2 AFR in each band calculated according to analytical and FEM approaches

According to fig.2, the computed numerical and analytical dependencies have modest disarrangement in each band of the filter.

From fig. 2 the -3dB level fractional bandwidth of the first passband ($TE_{01\delta}$ mode) is 0.68% at the center frequency of 6.09 GHz with the insertion loss of 1.8 dB in the first band, while the -3dB level fractional band-width of the second passband ($TE_{02\delta}$ mode) is 0.5% at the center frequency of 6.57 GHz with the insertion loss of 2dB in the band. Out-of-band rejection between passbands is about 60 dB. The spurious product is located at 7.41GHz.

Conclusions. The novel dual-band filter based on three elongated rectangular DRs has been developed, operating in two modes, namely $TE_{01\delta}$ and $TE_{02\delta}$. The derived analytic model of dual-band filter is well-consistent with FEM simulation results. The proposed dual-band filter has the advantage of absence of additional coupling elements and can be used in front-ends of multiband applications in wireless networks after retuning to the suitable frequency range.

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