Incorporating a Lowpass Filter into a Very Wide Bandpass Filter to Suppress Harmonics

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***Abstract*—This paper presents an algorithm for suppression of higher harmonics in response of the very wide bandpass filter (WBPF). Lowpass filter (LPF) is incorporated into the very wide bandpass filter to suppress harmonics. The LPF is consists of only three identical cells with uniform open stubs. At least two higher harmonics are suppressed.**

***Index Terms*— Microwaves, Suppression of higher harmonics for very wide bandpass filter, Ideal model.**

I. Introduction

ONE disadvantage of common bandpass filters is existing of higher harmonicas causing a narrow bandstop region on higher frequencies outside bandpass. This is specially a problem for the very wide bandpass filter (WBPF) like one presented in [1]. Common solution is incorporating lowpass filter (LPF) into the WBPF [2,3]. The solution intends not to significantly degrade bandpass characteristics but suppress higher harmonics. In the same time slow-wave characteristic of the lowpass filter shortens (minimizes) the structure. Problems can be nonuniform open stubs in [2] or too many different uniform open stubs like in [3].

Starting WBPF is from reference [1] with 150 % relative bandwidth. Ideal transmission structure and its response are presented in Fig. 1 and Fig. 2 in program package WIPL-D [4]. As can be seen in Fig. 2, bandstop region between the first bandpass and the next harmonic is narrow.

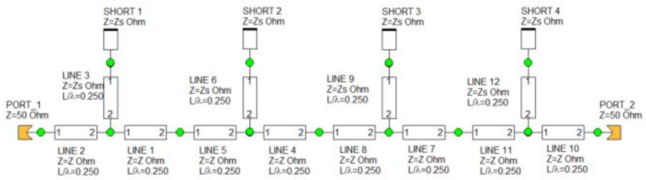

Fig. 1. Model of the ideal bandpass filter for relative bandwidth 150 %, presented in [1].

The aim is to suppress at least one higher harmonic. From Fig. 1 can be seen that transmission line segments between shorted stubs are λ/2 (2 x 0.250 λ), in phase π. To incorporate lowpass filter, the segment between the second and the third shorted stub is replaced with a lowpass filter. An example of a lowpass filter is chosen from [5]. It can be constructed of identical cells.

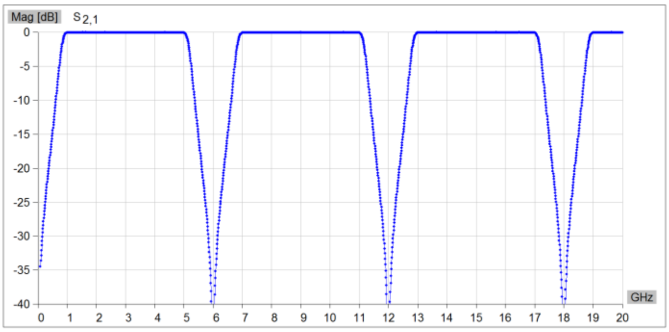

Fig. 2. S_{21} parameters for the filter around 3 GHz in the Fig. 1 with higher harmonica.

II. The Method

The method of incorporation of the lowpass filter is presented in Fig. 3. Instead of a transmission line segment π (λ/2 = 2 x 0.250 λ in upper Fig.3) between shorted stubs there are three equal cells of the lowpass filter, each with (*L1* + *L1*)* λ distance on the main line (3 x (*L1* + *L1*)* λ) in down Fig. 3). The phase difference π/3 is replaced with a cell presented in Fig. 4 with (*L1* + *L1*)* λ distance on the main line.

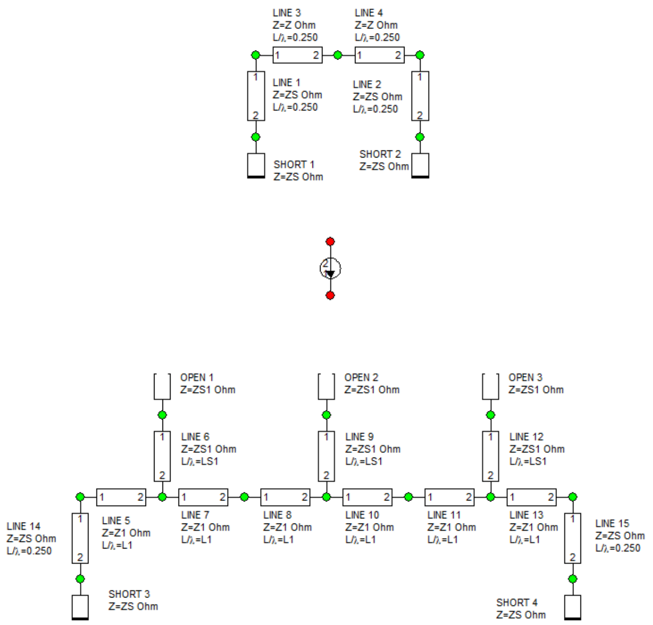

Fig. 3. Equivalence for incorporating low pass filter into bandpass filter.

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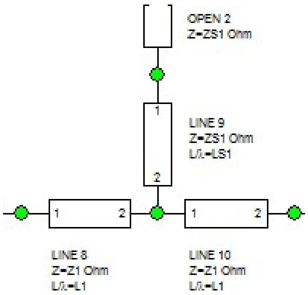


Fig. 4. One cell of the incorporated lowpass filter.

$A_cB_cC_cD_c$ matrix for the section π/3 of the primary filter with characteristic impedance *Z*, Fig. 1, is equaled on central frequency at 3 GHz with calculated ADCD matrix of the cell in Fig. 4. *L1* in Fig. 4 corresponds to phase difference *t1*, $L1 = t1/(2\pi)$. *Z1* is characteristic impedance of the main line and *ZS1* is characteristic impedance of the open stub. *LS1* corresponds to phase *tS1* of the open stub, $LS1 = tS1/(2\pi)$.

Calculation process is presented in Fig. 5 according to the reference [5], $Y = C_s/A_s$. Entering parameters are *Z*-characteristic impedance of the primary filter, *ZS*-characteristic impedance of the shorted stub of the primary filter (not in calculation, only in final results), *ZS1*-characteristic impedance of the open stub. *tS1*- phase length of the open stub was firstly treated as an entering parameter but later it is equaled with *t1* to get better response of the lowpass filter according to [5]. Output parameters are *t1* (*L1*) and *Z1*.

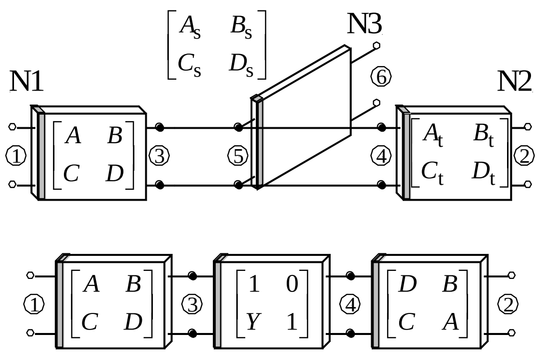


Fig. 5. Transformation of the cell in the Fig. 1 via ABCD matrix according to [4].

Equaled elements of matrix are presented in (1)-(3).

$$A_c(\pi/3) = \cos(\pi/3) = D_c(\pi/3) = AD + BC + BC_s\frac{D}{A_s} \quad (1)$$

$$B_c(\pi/3) = jZ\sin(\pi/3) = 2AB + C_s\frac{B^2}{A_s} \quad (2)$$

$$C_c(\pi/3) = j\sin(\pi/3)/Z = 2CD + C_s\frac{D^2}{A_s} \quad (3)$$

The corresponding ABCD-parameters for the cell in Fig. 4 are: $A = D = \cos(t1)$, $A_s = \cos(tS1)$, $B = jZ1\sin(t1)$, $C = j\sin(t1)/Z1$ and $C_s = j\sin(tS1)/ZS1$.

Solution for $Z1$ from (1) and from (3) are (4) and (5) respectively

$$Z1 = \frac{ZS1\cdot(2\cos(2\cdot t1)-1)}{\sin(2\cdot t1)\cdot tg(tS1)} \quad (4)$$

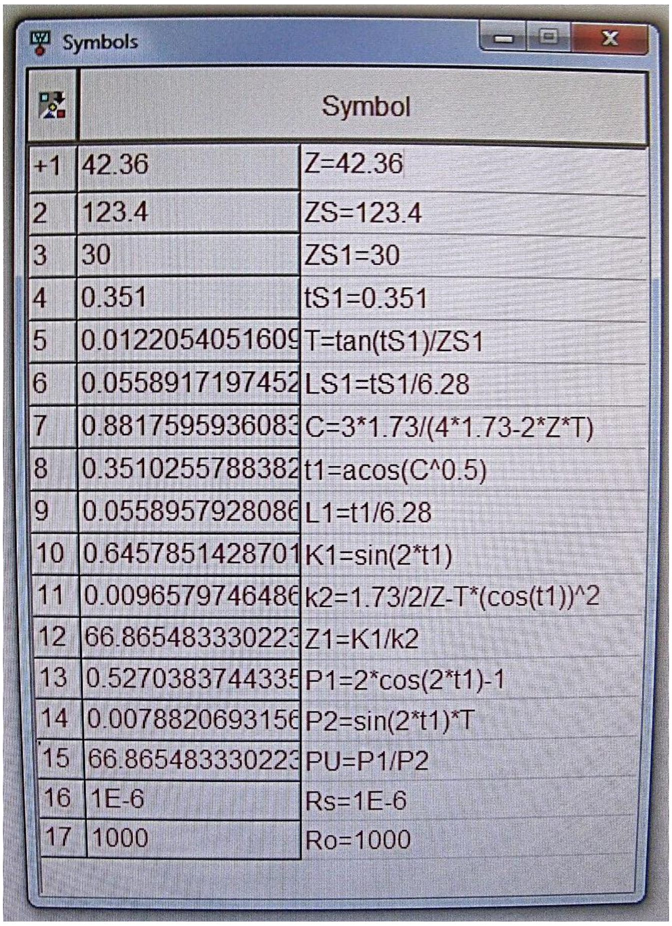
$$Z1 = \frac{\sin(2\cdot t1)}{(\sqrt{3}/(2\cdot Z) - (\cos(t1))^2\cdot tg(tS1)/ZS1)} \quad (5)$$

Next, equal solutions from (4) and (5). After rearranging

$$(\cos(t1))^2 = 3\sqrt{3}/(4\sqrt{3} - 2Z(tg(tS1)/ZS1)) = C \quad (6)$$

$$t1 = a\cos(\sqrt{C}) \quad (7)$$

Return (5) to solution for $Z1$ and calculate $Z1$. Calculation in WIPL-D Microwave Pro v5.1 [4] is presented in Fig. 6. $Z1$ is firstly calculated via (6) and then checked via (5) (*PU*).


Symbols

		Symbol
+1	42.36	Z=42.36
2	123.4	ZS=123.4
3	30	ZS1=30
4	0.351	tS1=0.351
5	0.0122054051609	T=tan(tS1)/ZS1
6	0.0558917197452	LS1=tS1/6.28
7	0.8817595936083	C=3*1.73/(4*1.73-2*Z*T)
8	0.3510255788382	t1=acos(C^0.5)
9	0.0558957928086	L1=t1/6.28
10	0.6457851428701	K1=sin(2*t1)
11	0.0096579746486	k2=1.73/2/Z-T*(cos(t1))^2
12	66.865483330223	Z1=K1/k2
13	0.5270383744335	P1=2*cos(2*t1)-1
14	0.0078820693156	P2=sin(2*t1)*T
15	66.865483330223	PU=P1/P2
16	1E-6	Rs=1E-6
17	1000	Ro=1000

Fig. 6. Calculation of parameters in WIPL-D Microwave Pro v5.1. *T*=tg(*tS1*)/*ZS1*. PU only checks calculation.

III. Results

Entering values for *Z* and *ZS* are chosen according to [1] for the very wide bandpass filter with relative bandwidth of 150

% around 3 GHz. The value of characteristic impedance of the open stub, *ZS1*, is chosen to induce equality of *tS1* and *t1* for better characteristics of the lowpass filter [5].

The values from Fig. 6 are incorporated into models in Fig. 7. The final filter is symmetrical as can be seen in Fig. 7. Additional resistivity is incorporated to suppress numerical problems, Fig. 6. Results for S_{21} and S_{11} for the final structure with the incorporated lowpass filter are presented in Fig. 7. More than two higher harmonics are suppressed. S_{11} is below -15 dB in the bandpass.

IV. CONCLUSION

The algorithm for incorporating lowpass filter into bandpass is presented. For example, it is applied to a very wide bandpass (WBPF) filter of 150 %. Such WBPF has narrow bandstop and wide higher harmonic that make problems in circuits. More than two higher harmonics are suppressed with incorporated lowpass filter. The lowpass filter consists of only three identical cells with uniform arms in the middle of the WBPF structure. The algorithm is applicable to other bandpass filters. Further research will include simulation and fabrication in microstrip.

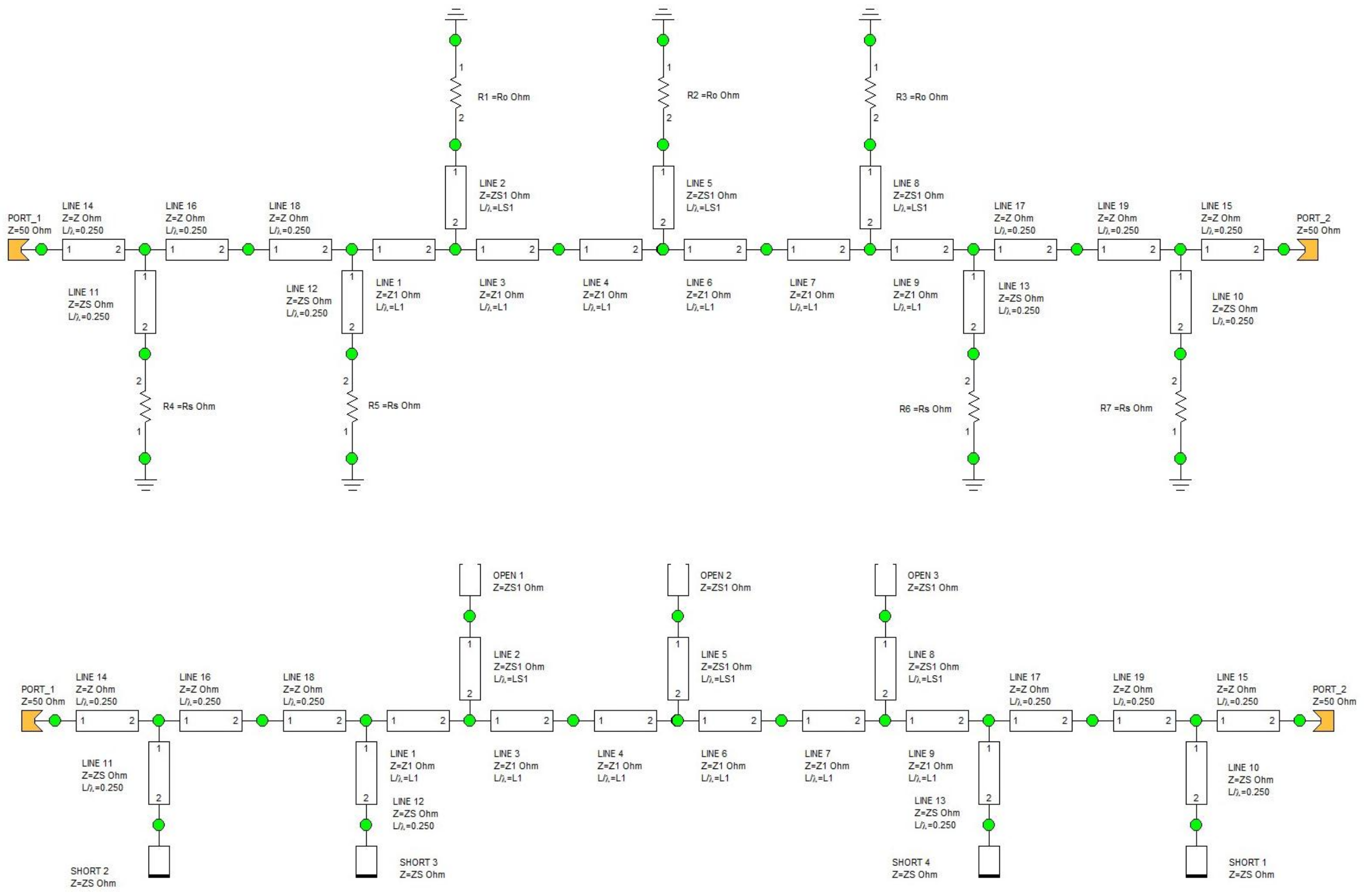


Fig. 7. Model of the lowpass filter incorporated into the bandpass filter, down model; the model with additional resistivity, upper model.

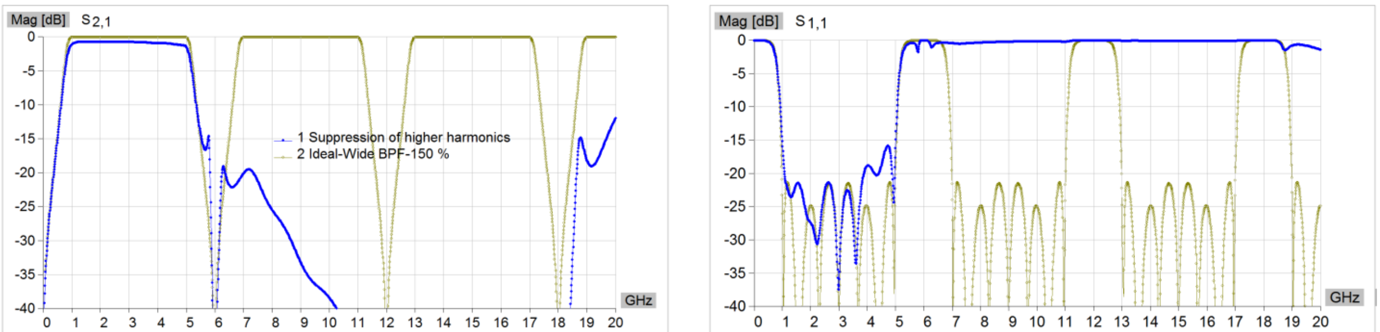


Fig. 8. S_{21} and S_{11} parameters for the resulting bandpass filter for *ZS1*-characteristic impedance of the open stub, equals 30 Ω.

ACKNOWLEDGMENT

This work was financially supported by Ministry of Education, Science and Technological Development of the Republic of Serbia (Grant No. 451-03-68/2020-14/200026).

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