CLASSES OF BANDPASS FILTERS HAVING AN ARBITRARY WIDE STOPBAND AND DESIGN TABLES FOR ONE SUCH CLASS

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ABSTRACT

Several new classes of bandpass filters having an arbitrary stopband width are defined and the general synthesis procedures for these filter classes are described. Furthermore, design tables for one particular class are given and practical results of a stripline filter are presented.

INTRODUCTION

Instead of using a highpass prototype network to obtain a periodic bandpass response, a bandpass prototype can be transformed to a similar response, but with an arbitrary wide stopband, as shown in Fig. 1 and described in (1). To date, no comprehensive design information has been published for these filters. Furthermore, no new classes have been defined and the possibility of eliminating lumped grounded capacitors has also not been discussed in the literature (2). It is shown in this paper how new classes can be defined easily by using different combinations of the circuit elements and by applying elementary network synthesis theory to each class. The element values of the final practical circuit of a particular class is then obtained by applying well-known network transformations to the original circuit, resulting in a symmetrical network that can be realized cheaply in stripline form without any chip capacitors.

DEFINITION AND SYNTHESIS OF DIFFERENT NETWORK CLASSES

Several different classes of prototypes that are bandpass are shown in Fig. 2 and they are called class 1, 2 and 3 respectively, of which the synthesis of a class 2 network will be described. Classes 2(a) and 2(b) are in fact special cases of the general class 2 type of network which has an arbitrary even number of unit elements. Its network structure is obtained when a double partial pole extraction from the impedance function is performed first at zero and infinite frequencies, followed by full pole extractions at finite frequencies from the remaining admittance function. Two non-redundant unit elements are then extracted to complete the basic synthesis cycle. Redundant unit elements must finally be introduced at the two ports of the untransformed network in order to apply the necessary Kuroda and Norton transformations, after which the two end sections will each consist of a symmetrical π-section and a unit element. Each fourth-order section consisting of two successive Foster sections is transformed to four cascaded unit elements terminated in an open circuit. The final circuit will then be symmetrical with respect to the element in the centre.

A summary of the properties of the three classes of networks is given in Table 1.

f = number of zeros at the origin.
g = number of zeros at infinity.
h = number of finite transmission zeros at one frequency.
i = number of non-redundant unit elements.
N = order of the network = f + g + 2h + i

Class	f	g	h	i	N
1	1	1	p	2(p+1)	2(3p+2)
2(a)	1	1	p	2(p-1)	6p
2(b)	1	1	p	4(p-1)	2(4p-1)
3	1	1	0	j	j+2

Table 1 : Properties of the different network classes.

DESIGN TABLES AND MEASURED RESULTS FOR A TWENTY-SECOND ORDER CLASS 1 NETWORK

In Tables 2 and 3 impedance values for the elements in a twenty-second order class 1 network, as shown in Fig. 3, are given. Because of the symmetrical property of the network, only half of the circuit, including the centre section, is characterized. The following definitions and abbreviations are used in the tables:

BW = relative bandwidth of a filter, based on the ripple bandwidth.

R = ripple level in dB.

k = ratio between the first resonant frequency and the lower edge frequency of the passband as shown in Fig. 1.

m = ratio between the centre frequency of the second passband and the centre frequency of the first passband.

The value of k is therefore an indication of the cutoff rate of the filter and m gives an indication of the improvement in stopband width compared to conventional filters, for which m = 3.

A filter having a bandwidth of 1 to 3 GHz was designed using the element values in the tables. A layout of the stripline centre conductor pattern is shown in Fig. 4 and a photograph of the filter with its top cover removed is shown in Fig. 5. The measured frequency response is shown in Fig. 6, which agrees well with the theoretical response.

CONCLUSIONS

Several new filter classes have been defined which can be used to obtain a bandpass filter with an arbitrary stopband width. These filters have the advantage that they are physically very small because the quarter-wave frequency is situated much higher than the centre frequency. Design tables for relative bandwidths of 90 and 100 percent are given and measured results for a stripline filter without chip capacitors are presented.

REFERENCES

(1) B.J. Minnis, "Classes of Sub-miniature Microwave Printed Circuit Filters with Arbitrary Passband and Stopband Widths", *IEEE Trans. Microwave Theory Tech.*, Vol. MTT-30, pp. 1893-1900, Nov. 1982.

(2) J. Ness and J. Dougall, "Microstrip Filters for Lower Frequencies", *RF Design*, Jan. 1987, pp. 52-61.

BW = 100% k = 0,86 m = 4

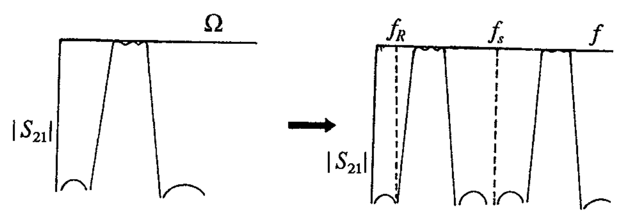
	RIPPLE (dB)				
	0,001	0,005	0,01	0,05	0,1
Z_{01}	66,03	73,85	78,53	94,54	104,95
Z_{02}	65,57	74,53	79,29	94,62	104,34
$Z_{03}=Z_{04}$	105,44	104,50	106,00	116,79	123,54
Z_{0e1}	242,27	193,49	183,47	176,27	180,11
Z_{001}	3,89	6,81	8,27	12,59	15,14
Z_{0e2}	149,50	143,36	143,66	152,68	161,59
Z_{002}	20,35	20,31	20,71	22,83	24,50
$Z_{e1}^{(1)}$	152,39	117,78	109,39	100,65	101,37
$Z_{e2}^{(1)}$	112,26	87,44	81,36	75,02	75,57
$Z_{e3}^{(1)}$	173,89	136,08	126,75	117,00	117,88
$Z_{e4}^{(1)}$	41,39	32,14	29,88	27,53	27,73
$Z_{e1}^{(2)}$	90,98	82,30	80,78	82,49	86,10
$Z_{e2}^{(2)}$	68,25	61,61	60,42	61,61	64,27
$Z_{e3}^{(2)}$	106,88	96,35	94,45	96,21	100,33
$Z_{e4}^{(2)}$	24,98	22,57	22,14	22,59	23,57

Table 2 : Characteristic impedances in ohm for a 100% bandwidth class 1 network.

BW = 90% k = 0,86 m = 4

	RIPPLE (dB)				
	0,001	0,005	0,01	0,05	0,1
Z_{01}	70,18	79,26	84,66	103,00	114,79
Z_{02}	71,03	81,40	86,68	103,64	114,71
$Z_{03}=Z_{04}$	111,36	112,18	114,06	126,90	135,83
Z_{0e1}	198,86	171,59	166,34	166,35	172,38
Z_{001}	5,93	9,35	11,11	16,42	19,59
Z_{0e2}	141,89	137,92	138,95	149,48	159,00
Z_{002}	24,66	24,95	25,55	28,45	30,65
$Z_{e1}^{(1)}$	125,30	100,70	94,78	89,45	90,92
$Z_{e2}^{(1)}$	88,67	71,45	67,27	63,48	64,51
$Z_{e3}^{(1)}$	166,95	134,72	126,87	119,72	121,63
$Z_{e4}^{(1)}$	45,04	36,25	34,12	32,20	32,73
$Z_{e1}^{(2)}$	79,70	73,30	72,37	74,85	78,53
$Z_{e2}^{(2)}$	56,77	52,10	51,41	53,10	55,68
$Z_{e3}^{(2)}$	107,27	98,36	97,01	100,12	104,96
$Z_{e4}^{(2)}$	28,75	26,42	26,07	26,94	28,26

Table 3 : Characteristic impedances in ohm for a 90% bandwidth class 1 network.



$$\Omega = \tan\left(\frac{\pi f}{2 f_s}\right)$$

f_s = quarterwave frequency
f_R = first resonant frequency

Fig. 1 : Mapping of bandpass to bandpass response according to Richards' transformation.

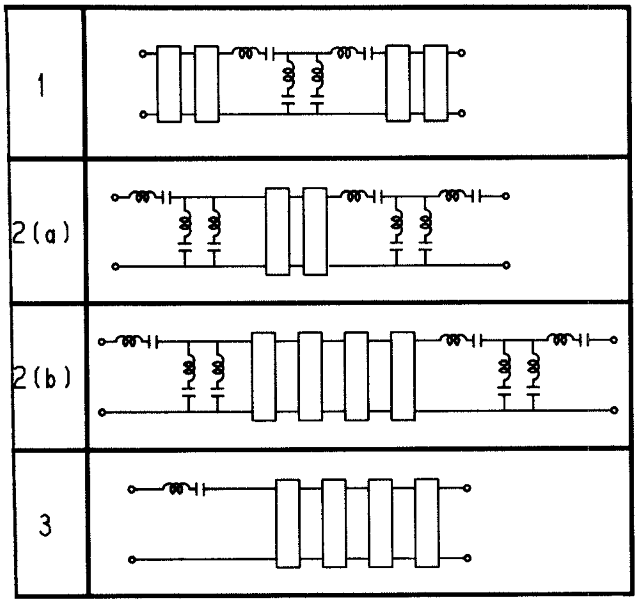


Fig. 2(a) : Different untransformed network classes.

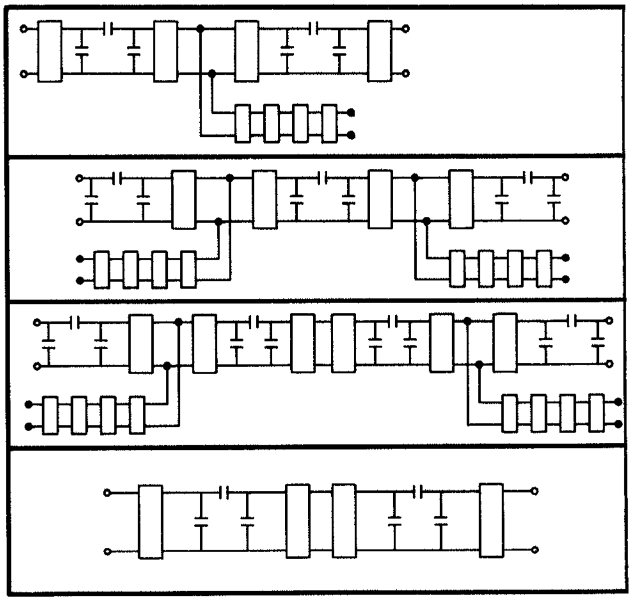


Fig. 2(b) : Different transformed network classes.

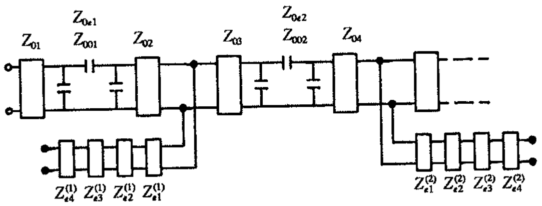


Fig. 3 : Circuit structure for a twenty-second order class 1 circuit.

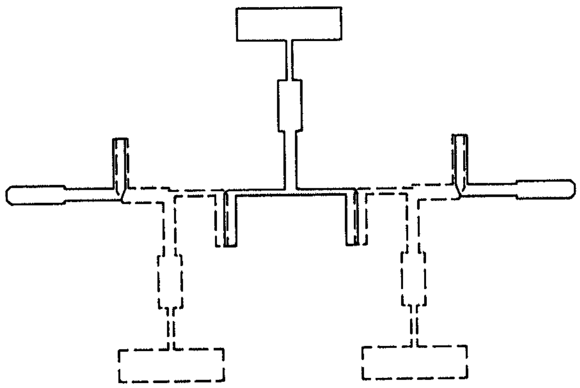


Fig. 4 : Layout of the centre conductor pattern of the designed filter.

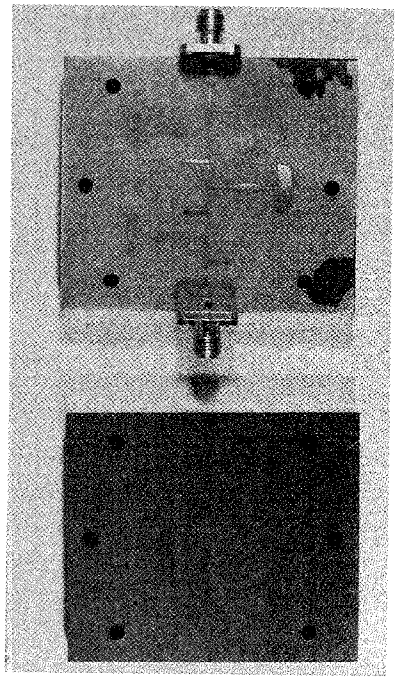


Fig. 5 : Photograph of stripline filter with top cover removed.

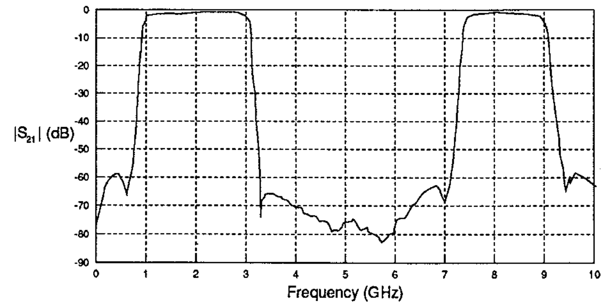


Fig. 6(a) : Measured transmission response.

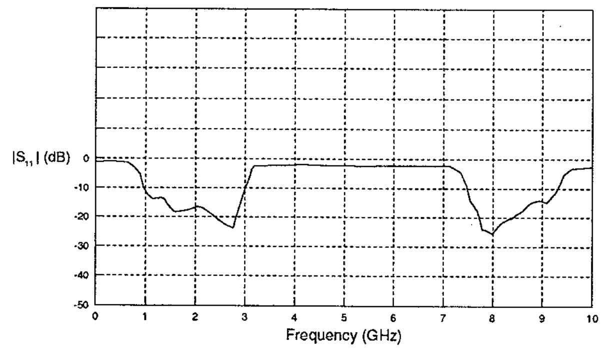


Fig. 6(b) : Measured reflection response