Design of Compact Multi-Channel Diplexer Using Defected Microstrip Structure

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Abstract- **In this paper, two compact quad-channel and six-channel diplexer are designed and fabricated using defected microstrip structure (DMS). This structure is designed for the desired frequency based on the literature reviews. The proposed configuration is composed of a conventional T-junction divider with two pairs of open bended stubs and dual/tri-band filters. In designing dual band filters, a loop resonator loaded with two stepped-impedance resonator and defected microstrip structure. In addition, by adding a pair of open stubs, tri-band responses easily achieved without increasing the circuit size. The operating mechanism in resonance frequencies by surface current density is obtained. As a result, the multi-channel diplexer occupies a compact size of 0.13λ_g by 0.13λ_g. The measured results are fully in agreement with the simulated predictions indicating that an isolation between channels is more than 29 dB.**

Index Terms- Compact Diplexer, Defected Microstrip Structure, Multi-Channel Diplexer.

I. INTRODUCTION

MULTIPLEXERS in multiple channels are widely used in microwave systems in recent years [1]. These multiplexers consist of multi-port matching circuits and channel filters. Microstrip matching circuit serves as a through pass filter at the center frequency of a channel filter while are open circuits at other filter center frequencies [2]. A multiplexer could be simplified as a diplexer [3] while operates at multiple frequencies and have several advantages such as compactness, low cost and no extra matching network.

A compact eight-channel diplexer with 16 stepped impedance resonators is presented [4] in which each channel was controlled by one pairs of stepped impedance resonator. As a result, increasing the number of channels increases the circuit size. In [5], multi-band bandpass filters employing stub loaded stepped-impedance resonator with defected microstrip structure (SL-SIR-DMS) is presented. The use of different DMS leads to an increase in the number of bands without increasing the resonator

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size. In [6], a compact dual-band bandpass filter using a loop resonator loaded by two modified T-shaped resonators, double T-shaped resonators, and open bended stubs is presented. The two passbands are achieved by adjusting spaces between the loop resonators and open bended stubs. In [7], a planar diplexer based on balanced CRLH-TL without lumped elements is reported.

In this paper, applying [5]-[7], a new compact quad-channel diplexer is proposed using the loop resonator loaded by stepped impedance resonator with defected microstrip structure (SIR-DMS). In addition, by improving the structure and adding open stubs, a six-channel diplexer is achieved without increasing the circuit size. Proposed structures is designed and fabricated in S and C frequency bands.

II. CONFIGURATION OF DIPLEXER

Fig. 1 shows the proposed structure of quad-channel and six-channel diplexer which designed by dual-band and tri-band filters, respectively. As shown in Fig. 1(a), proposed diplexer contains two unit cells that are combined by two pairs of open bended stubs with a conventional T-junction divider. Each unit cell is a bandpass filter. As shown in Fig. 1(b), a dual-band filter is composed of a loop resonator and SIR with a slot the middle of it, also a C-shape DMS with two via inserted into the low impedance lines, which make the microstrip line shorted with ground. The reason to choose stepped impedance is to achieve low pass characteristics and slot gives high pass characteristic, so combination of both gives the bandpass characteristics [8]. DMS increases the electric length of the microstrip line and makes the effective capacitance and inductance increase, as a result the operating frequency lowered which effectively reduces circuit size [9]. In Fig. 1(c) a six-channel diplexer which designed by tri-band filters is shown. This six-channel diplexer obtained by adding two pairs of open stubs such as [10]-[11]. Dimensions of the proposed diplexer, as shown in Fig. 1, are listed in the table I.

The LC equivalent circuit of the tri-band filter is shown in Fig. 2. Moreover, the electrical equivalent of open circuit stub, DMS and vias is marked in the following sections.

The slot introduces some series capacitance (C_{g3}) due to fringing field convergence or stub couplings [12]. The T-shape stub is grounded with a pair of vias which establish two parallel inductances. In addition, the DMS in the microstrip line disturbs the current distribution which therefore, enhances the inductance and capacitance of the line [13]. Any open-stubs less than λ/4 act as a shunt capacitor [14].

As shown in Fig. 3, our proposed structure introduces many adjustable parameters, in the circuit. Therefore, we may achieve to reduce the circuit resonance frequency by manipulating these parameters (increase the loop resonator length (Fig. 3(a)), DMS length (Fig. 3(b)), and the opening stubs length (Fig. 3(c))).

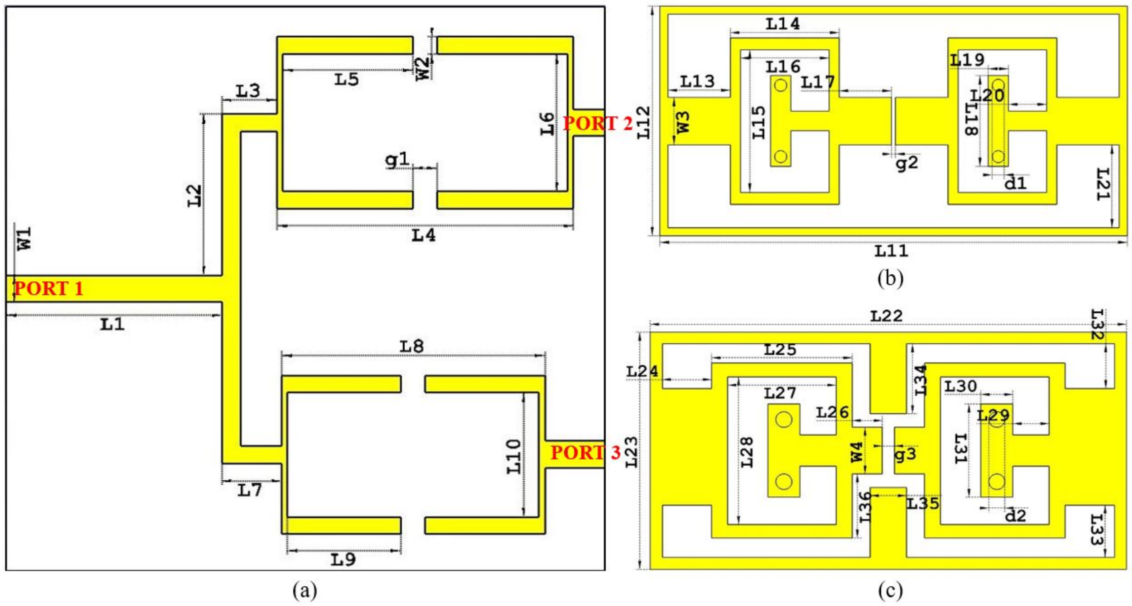


Fig. 1. Structure of proposed multi-channel diplexer. (a) General configuration of two channel diplexer with bandpass filter unit cell, (b) quad-channel diplexer with dual-band unit cell, (c) six-channel diplexer with tri-band unit cell.

Table I. Parameters of the proposed diplexer, (unit1/unit2) (units are in mm).

L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**
9	7.1	2.3	12.4	5.4	6.1	2.5	11	4.7
L10	**L11**	**L12**	**L13**	**L14**	**L15**	**L16**	**L17**	**L18**
5.5	11.6/10.9	5.8/5.1	1.6/1.3	2.7/2.4	3.5/3.2	2.1/1.8	1.3/1	2.3/1.9
L19	**L20**	**L21**	**L22**	**L23**	**L24**	**L25**	**L26**	**L27**
0.5/0.4	0.8/0.7	2.3/1.9	11.8/10.8	6.1/5.9	1.2/1	3.5/3.2	0.7	2.5/2.2
L28	**L29**	**L30**	**L31**	**L32**	**L33**	**L34**	**L35**	
3.5/3.4	1.3/1.1	0.8	2.4/2.2	1.1/0.9	1.4	1.8/1.5	0.9/0.8	
W1	**W2**	**W3**	**W4**	**g1**	**g2**	**g3**	**d1**	**d2**
1.2	0.8	1.2	1.2	1	0.1	0.3	0.3	0.4

III. SIMULATED AND MEASURED RESULT

The proposed structure is simulated, designed and fabricated on a single layer Rogers RO4003C substrate with a dielectric constant of 3.38, a loss tangent of 0.0027, and a thickness of 0.508 mm. Here, EM software CST is used for simulation, and a vector network analyser is used for our measurements.

Fig. 4 shows the photograph, simulated and measured results of the quad-channel diplexer. The overall circuit size is 22.3 × 20.5 mm^2, i.e., approximately $0.13\lambda_g \times 0.13\ \lambda_g$ (where λ_g is the guided wavelength at center frequency of 1st passband). The quad-channel diplexer has simulated/measured in center frequencies at port 2 (3.6/3.5, 5.7/5.7 GHz) and port 3 (4.1/4, 6.2/6.3 GHz), the 3-dB

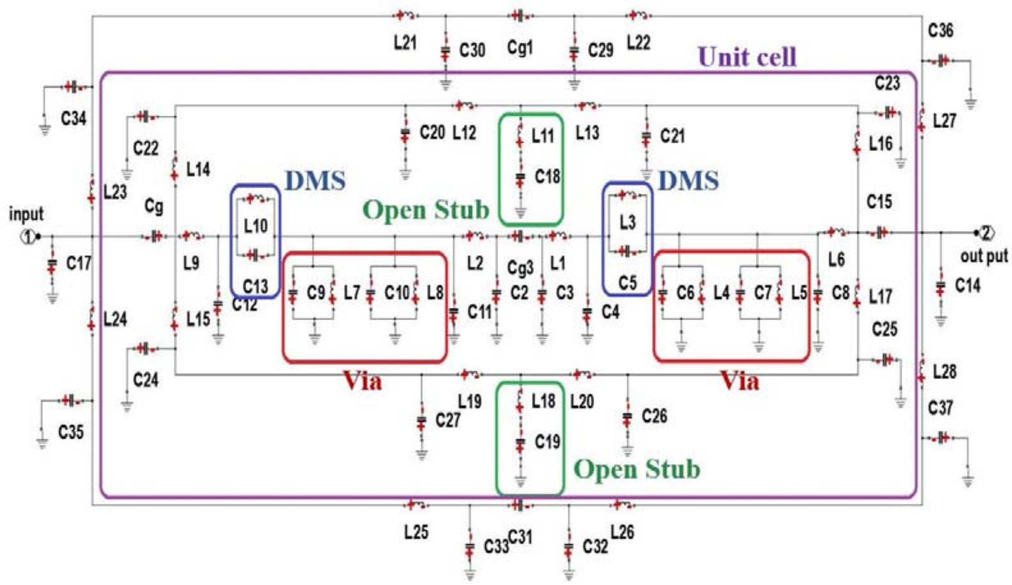
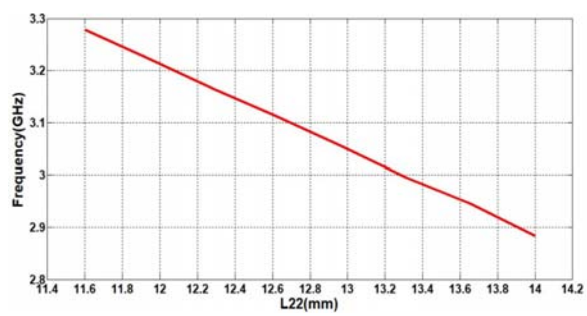
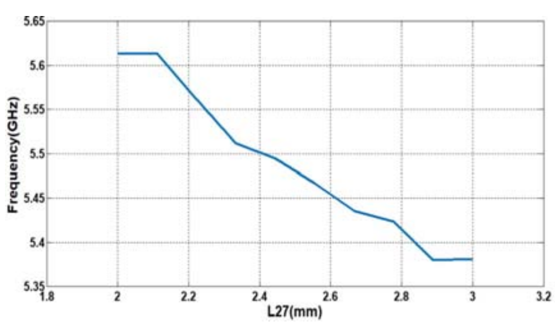
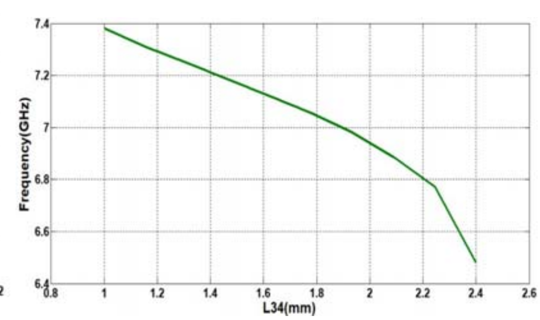


Fig. 2. LC circuit of the filter.



(a)



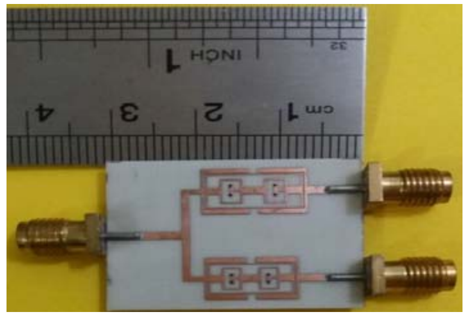


(b) (c)

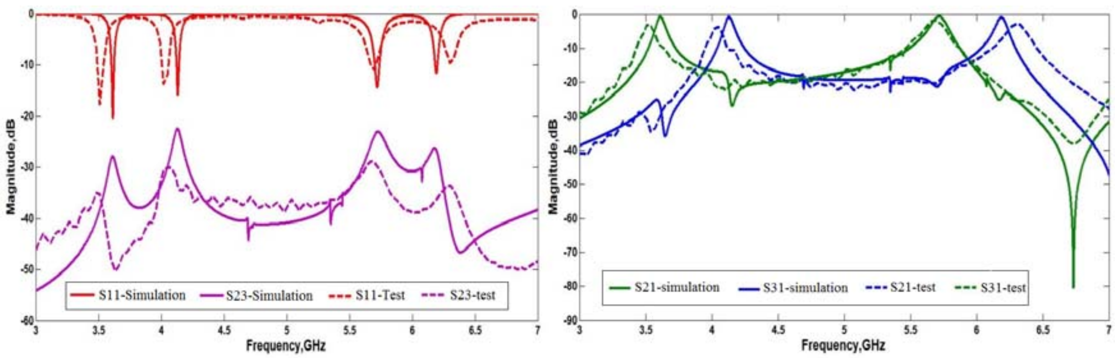
Fig. 3. The resonance frequency versus length, (a) the loop resonator length, (b) DMS length, and c) the open stubs length.

fractional bandwidth (FBW) are of 5.2%/5.7%, 6.2%/7% , 5%/3.7%, and 5.3%/5.5%, the minimum insertion loss (-20 log |S21|*)* of 0.8/3, 0.5/2, 0.8/3.2, and 0.9/3.1 dB and the return losses (-20 log |S11|*)* are around 20/10 dB for each channel. The isolation among channels is greater than 25/29 dB.

The six-channel diplexer can be achieved easily with adding open stubs in center of the loop resonator. Fig. 5 illustrates the photograph, simulated and measured results of six-channel diplexer. Similarly, the six-channel diplexer has simulated/measured in center frequencies at port 2 (3.4/3.4,

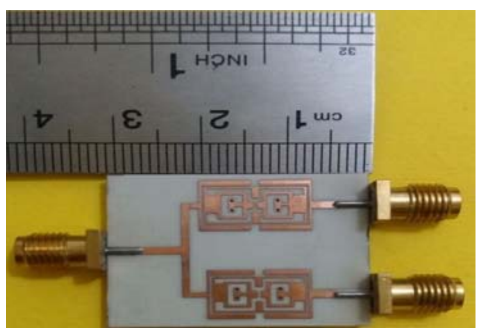


(a)

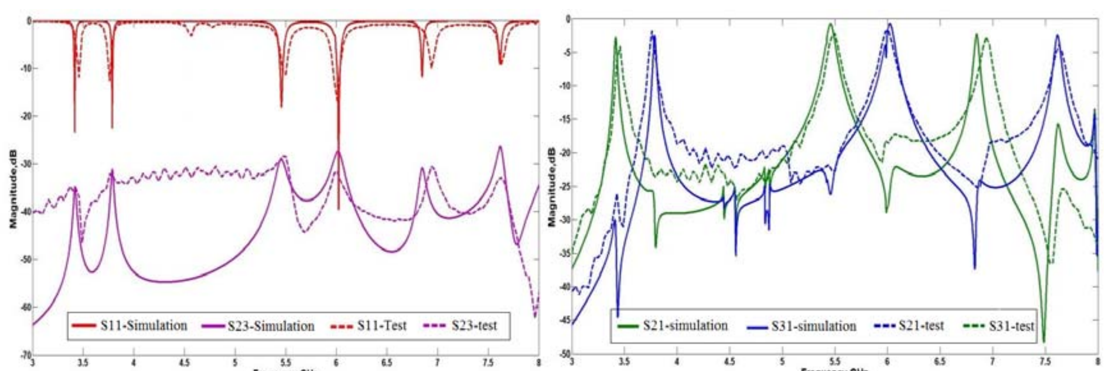


(b)

Fig. 4. Proposed quad-channel diplexer, (a) Photograph, (b) Simulation and measurement results.



(a)



(b)

Fig. 5. Proposed six-channel diplexer, (a) Photograph, (b) Simulation and measurement results.

Table II. Simulation and measurement results for quad-channel and six-channel diplexers.

RESULT	Frequency(GHz)	FBW(%)	insertion loss(IL) (dB)	ISO (dB)
SIMULATED QUAD-CHANNEL DIPLEXER	3.6/4.1/5.7/6.2	5.2/5/6.2/5.3	0.8/0.8/0.5/0.9	25
MEASURED QUAD-CHANNEL DIPLEXER	3.5/4/5.7/6.3	5.7/3.7/7/5.5	3/3.2/2/3.1	29
SIMULATED SIX-CHANNEL DIPLEXER	3.4/3.8/5.5/6.1/6.9/7.6	1.7/1.8/4.6/5.6/2.9/1.8	2.4/2.2/0.7/0.6/2.1/2.1	29
MEASURED SIX-CHANNEL DIPLEXER	3.4/3.7/5.6/6/7/7.6	2.8/2.7/3.6/6/3.4/3.2	3.5/2/1.5/1/3/3	32

5.5/5.6, 6.9/7 GHz) and port 3 (3.8/3.7, 6.1/6, 7.6/7.6 GHz), the 3-dB fractional bandwidth (FBW) are of 1.7%/2.8%, 4.6%/3.6%, 2.9%/3.4%, 1.8%/2.7%, 5.6%/6%, and 1.8%/3.2%, the minimum insertion loss of 2.4/3.5, 0.7/1.5, 2.1/3, 2.2/2.2, 0.6/1 and 2.1/3 dB and the return losses are around 20/10 dB for each channel. The isolation among channels is greater than 29/32 dB. All results are listed in Table II.

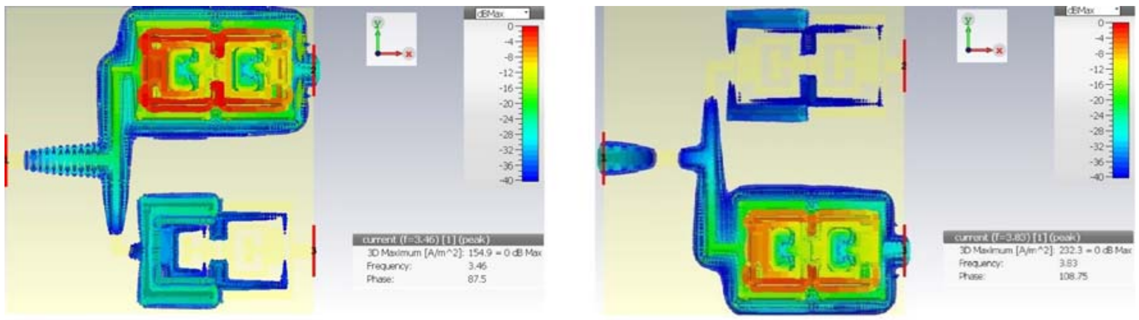
Although the measured results verify the simulated results, there are some insignificant deviations on their values. These deviations are duo to manufacturing tolerances and SMA connectors wastage and impedance mismatch duo to the vias positions.

Fig. 6 depicts the surface current distribution at each operating frequency bands. This current distribution density represents the control mechanism at every resonant frequency with the corresponding electrical length. As shown in this figure, the strong and weak coupling effects are illustrated by the red and blue colors, respectively. In other words, the surface current distribution represents the electromagnetic wave transfer from the input port to the output port at every resonant frequencies.

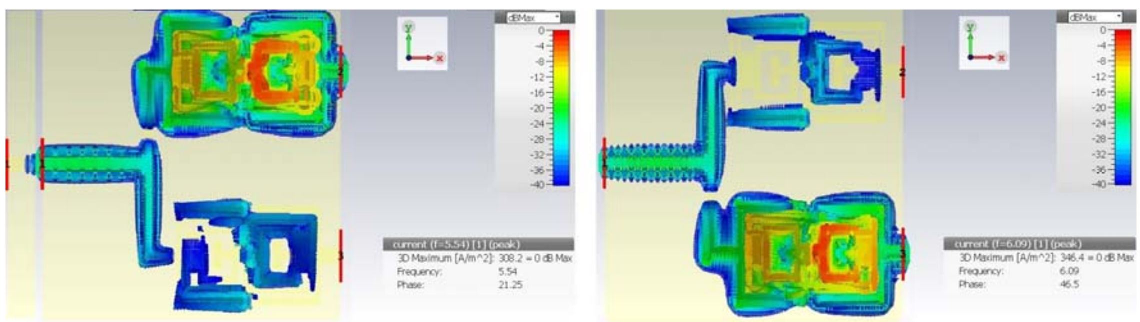
The current distribution is concentrated consecutively on the loop resonators at 3.4 and 3.8 GHz, Fig. 6(a), stub loaded stepped-impedance resonator with defected microstrip structure (SL-SIR-DMS) at 5.5 and 6.1 GHz, Fig. 6(b), and open circuit stubs at 6.9 and 7.6 GHz frequencies, Fig. 6(c). Finally, a performance comparison between the proposed diplexers with ref. [1] and ref. [4] is listed in Table III.

IV. CONCLUSION

We have proposed a compact multi-channel diplexer and the results were verified through both an EM simulation and experiment. The proposed structures illustrates advantages of the compact size, low insertion loss, and sharp response. Also, good agreement between the simulation and measurement results is achieved. Therefore, the multi-channel diplexer is suitable for the multi-band and multi-service wireless communication applications.



(a)



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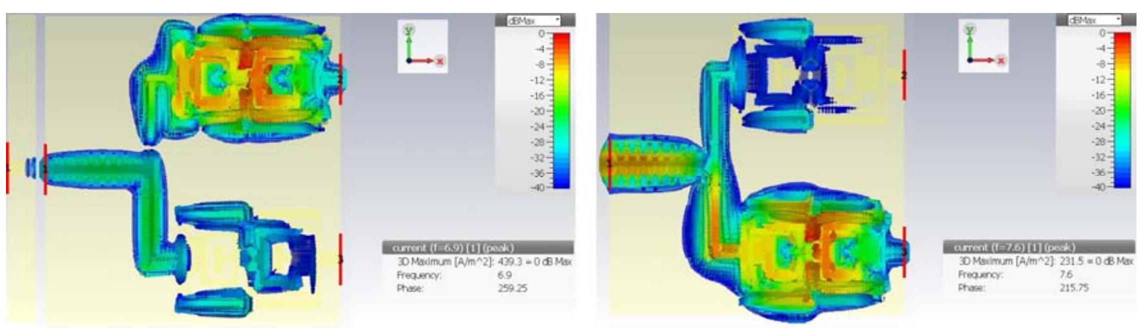

(c)

Fig. 6. Surface current distribution in six-channel diplexer at different frequencies. At (a) 3.4 and 3.8 GHz, (b) 5.5 and 6.1 GHz, and (c) 6.9 and 7.6 GHz.

Table Ⅲ: Performance comparison between the proposed diplexers with references.

Ref.	f (GHz)	IL (dB)	FBW (%)	ISO (dB)	ε_r	Size (λ_g^2)
[1]	1.5/1.8/2.4/3.5/5.2/5.8	1.5/1.1/1.5/1.2/2/2	7.6/8/5/6.5/1.9/1.7	30	2.2	0.027
[4]	0.9/1.5/2.1/2.7 /1.2/1.8/2.4/3	2.1/ 2.3/ 2.4/ 2.6/ 2.3/ 2.2/ 2.8/ 2.3	4.3/ 4/ 3.5/ 3.5/ 3/ 3/ 2.7/ 2.7	29	10.2	0.1
4-ch	3.5/4/5.7/6.3	3/3.2/2/3.1	5.7/3.7/7/5.5	25	3.38	0.01
6-ch	3.4/3.7/5.6/6/7/7.6	3.5/2/1.5/1/3/3	2.8/2.7/3.6/6/3.4/3.2	32	3.38	0.01

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