Band-pass limiting filter based on microstrip comb line structure

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Abstract

A band-pass limiting filter (BPLF) based on a microstrip comb line loaded with PIN diodes is proposed in this letter. In contrast to conventional comb line filter designs, the BPLF utilizes PIN diodes to replace capacitor components. When the power of the input signal is below a certain level, the proposed BPLF acts as a filter. While for an input signal whose power is above a certain level, it behaves like a limiter. According to measurement data, the proposed BPLF has a broad passband with an insertion loss of about 3.5 dB from 8.2GHz to 9.0GHz, and a low limiting level of less than 17dBm with a high power input of 50W (47dBm). In general, the proposed BPLF enables dual selectivity of frequency and power, and can be applied to the front end of RF channels.

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Introduction: Filters and limiters are both important components in radio frequency (RF) systems, to achieve frequency filtering [1] and protection performance [2], respectively.

In general, filters are designed to allow in-band high power signals through with low loss, so that sensitive devices in the back end may be damaged. On the other hand, limiters based on PIN diodes are designed to have ultra-wideband [3], low insertion loss or integrated with amplifier [4], rather than high selectivity. Therefore, in order to ensure frequency selection and prevent the damage, the filters and limiters are cascaded together. However, it is costly and not easy to integrate and reduce insertion loss if the cascade is adopted directly in front of the RF receiver as usual.

Here we proposed a basic concept of integrating the design of filters with limiters based on the basic comb line bandpass filters, which is abbreviated to BPLF. As a kind of classic band-pass filter structure, microstrip comb line [5], is easy to design and implement. It is comprised of an array of coupled resonators in parallel, which are short-circuited at one end, and with lumped capacitances loaded between the other end and ground. Due to the presence of lumped capacitances, the resonators can be shortened thereby reducing area of the structure. In addition, it is possible to design reconfigurable filters by controlling the value of the loaded capacitances or adjusting lumped elements, such as frequency-tunable [6-8] and switchable filters [9].By replacing lumped capacitors with PIN diodes, filtering performance under small signals and protection effect under large signals can be achieved together with a more compact size and a lower insertion loss compared to the cascade design. It can be used to deal with intentional or unintentional electromagnetic interference in complex electromagnetic environments.

*Principle and design:*Fig.1 shows the principle of the proposed BPLF. The topology in the middle part was modified from the equivalent circuit of a comb line filter [10]. The key point of the modification is to replace the shunt capacitor with a PIN diode (inside the blue box in Fig.1). Under the input with low power, the diodes are equivalent to capacitances in the turned-OFF state (inside the green box). Thus, the circuit shows the characteristics of a bandpass filter. On the contrary, if the power of input electromagnetic signals exceeds the threshold, diodes work in a turned-ON state and is equivalent to a resistance approximate to zero (inside the red box). Therefore, the switching process of PIN diodes can be used to realize limiting properties. The other parts of the topology include transformers at input and output, parallel shorted shunts, and J inverters. and in Fig.1 represent admittance of the terminating line and parallel stub, respectively, the same as the comb line filter equivalent circuit.

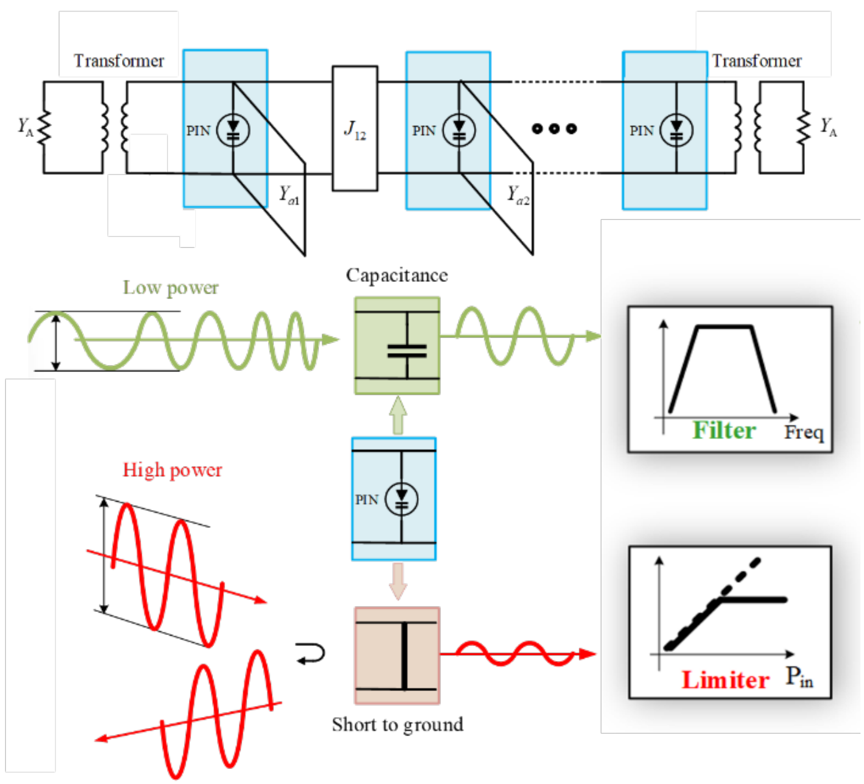

Fig 1 *Principle of the proposed BPLF*

Fig.2 shows the geometry of the proposed BPLF with a typical microstrip comb structure. Based on the theory of the microstrip coupled line, every two adjacent coupled lines are equivalent to a J inverter as shown in Fig.1. A 7-order filter is achieved with 7 microstrip resonant structures that are shorted with metal vias. PIN diodes are loaded between the other end of the resonant element and the ground. The proposed BPLF uses the tapped line at the input and output ports, which is equivalent to a transformer.

The dielectric substrate is made of alumina ceramic with a relative dielectric constant = 9.8 and a loss tangent of 0.001. The key parameters S_1 = 0.24mm, S_2= 0.63mm and S_3 = 0.75mm are determined by the coupling matrix. Other parameters are listed in table 1. These dimensions have been optimized to obtain resonance at 8.5GHz.

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Fig 2 *Structure of the proposed BPLF*

Table 1. Parameters of the structure

Parameter	W_1	L_1	H_1	L_2	L_3	W_2	H_2	D_1
Value(mm)	0.78	7.52	0.38	2.00	3.85	0.31	0.005	0.3

Simulation and analysis: The final circuit was simulated, where the junction capacitance of the PIN diodes was set to 0.2pF. Fig.3 shows the transmission coefficient when the diode is progressively turned on. It can be seen that when the PIN diodes are off, the proposed BPLF exhibits filterability. As the number of triggered-on PIN diodes increases, the isolation grows, showing better protection performance.

As for the response process, Fig.4 shows the waveforms of the input and output. It can be seen that the output power remains almost the same for 1W, 4W and 16W input levels, which means well flatness. Also, it can be observed that response time is at the nano-second level.

Experimental results: In Fig.5, the comparison of simulation and test results in the small-signal state is plotted. It can be seen that the return losses at the input and output ends are better than -15dB. The insertion loss at 8.2 to 9.0 GHz is about 3.5dB in passband. As a bandpass filter, its relative bandwidth reaches 9.3%.

The limiting measurement performance in different frequencies and the assembled BPLF with the dimension of 14.5mm*10.5mm*0.385mm are shown in Fig.6. The alumina surface film process is adopted for fabrication of the structure and micro-assembly technology is adopted to bond PIN diodes. The details are shown in Fig.7. The pulse width of tested high power signal is 1us and the period is 1ms. The results show that the threshold level of the BPLF is about 13dBm and the limiting level is less than 17dBm with 50W injection.

Conclusion: A concept of BPLF based on comb line structure has been presented and experimentally investigated, exhibiting dual selectivity of frequency and power, which is significant for receiver in the complex environment.

Fig 3 *Frequency responses of structures when different number of PINs are triggered on*

Fig 4 *3 power levels input with their corresponding output*

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Fig 5 *Simulation and measurement results of transmission characteristics in the small-signal state*

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Fig 6 *Measured results of power injection and BPLF picture*

Fig 7 *BPLF details under the microscope*

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