HTS Microwave Power Limiter Based on Microstrip Quarter-Wave Resonators

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Abstract **– A microwave power limiter based on three-pole microstrip filter is designed, fabricated and tested. In the device outer resonators are coupled through an inner resonator containing high-temperature superconducting film. Prototype of the device with central frequency 8.3 GHz and relative bandwidth 7% has insertion loss 3 dB in the open state and signal suppression not less 35 dB in the limitation state.**

Index Terms **– microstrip resonator, HTS, power limiter, interaction of resonators**

I. Introduction

ALMOST ALL the radar receiver systems need microwave power limiter (PL) for protection input circuit form high power pulses. Semiconducting limiters are widely used in modern receiver equipment [1]. These do not possess acceptable performance (electrical strength and switching time). Also it is necessary to mention about another class of devices of this type, the so-called cyclotron limiters [2]. They demonstrate good electric characteristics (switching time, high level of attenuation in limitation mode) but they demand significant magnetic field for operating. This factor leads to an increase in device dimensions and weight.

The first attempts of applications of high-temperature superconducting (HTS) materials for power limitation began after their discover. Phase transition time from superconducting to normal state for this material does not exceed 10^{-10}c [3]. Microwave PL taking a form of 50-Ohm coplanar line made from HTS thin film is described in Ref. [3, 4]. The material of this PL passes to normal state when power in the device exceeds certain level, which causes conductivity of HTS line dramatically reduction. As a consequence, transmitting power is limited. It is important to notice, almost all input power is absorbed by the device in this case.

Recently [5, 6], we designed a new type of HTS PL in which incident power is reflected from the input of the device at the limitation state. This limiter in the open state is a bandpass filter with low transmission loss. Device has three microstrip resonators. Configuration of outer resonators and spacing between them provides mutual compensation of inductive and capacitive interactions at the resonant frequencies. In this case damping pole is observed at a frequency of the first passband and almost all power reflects from the device's input. The outer resonators are coupled to each other only through the center one which has HTS-element in its middle part. Conductivity of HTS-element reduces when input power exceeds the critical level. Due to this effect quality factor of the central resonator falls. As a result, coupling between the outer resonators is broken and the device passes to the limitation mode.

II. Problem Definition

The PLs designed on the base of reflective principle show adequate electrical properties and electrical strength [5, 6]. But compactness of the modern microwave receiver equipment is an important issue. One of ways to reduce sizes of power limiters is to use quarter-wavelenght microstrip resonators for their creation. It is known [7] that for a two-resonator structure based on quarter-wavelength stepped-impedance microstrip resonators it is possible to choose such distance between them that the total coupling coefficient be equal zero at a frequency of the passband. The microwave power limiter, whose outer resonators are quarter-wavelenght and stepped-impedance, is presented in this work.

III. Theory

The considered structure of power limiter (Fig.1) represents itself a bandpass filter which consists of three microstrip resonators. Strip conductors of the input and output resonators *3* are completely made from copper. They are stepped-impedance and their high-impedance parts are grounded. The third resonator is composite. It consists of copper patches *4* and dumbbell HTS-element *7* which fulfilled on separate substrate *6*. All copper conductors (*3*, *4*) are made on substrate *1*, the bottom surface *2* of which is completely metal-coated. Thin silver layers deposited on wide parts of HTS-element are responsible for galvanic contact between patches *4* and HTS-element *7*. The copper foils *5* are used for galvanic coupling between patches *4* and HTS-element *7*.

The inner resonator is half-wave, and its resonant frequency is equal to the frequencies of the outer quarter-wave resonators. It is known, antinodes of the microwave current at a resonant frequency locate in the central part of the half-wave resonator. Thus in the open-state state the device is a bandpass filter with small transmission loss. Its bandwidth is defined by value of gap S_2.

In absence of middle resonator damping pole appears at a frequency of the passband. It is connected with the fact of a

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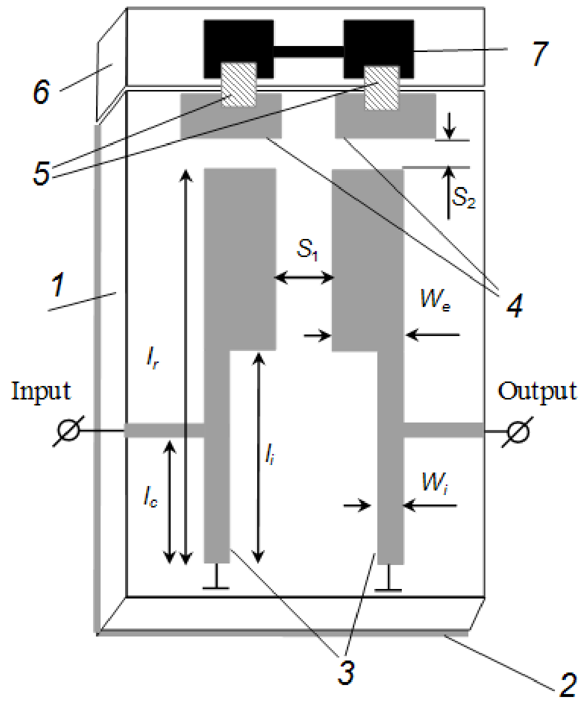

Fig. 1. Design of the microstrip power limiter

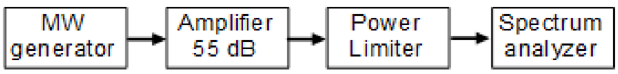

Fig. 2.Scheme of transfer characteristic measurement.

total coupling coefficient between outer resonators *3* is equal to zero. This is due to that in the such two-resonator structure inductive and capacitive coupling coefficients have the same magnitudes, but have different signs.

IV. Experimental Results

In Fig. 1, the strip conductors topology of the power limiter is shown, where designations of the designing parameters are also presented. The device was simulated with help a Sonnet Lite and following design parameters were obtained. The alumina substrate with a thickness of 0.5 mm (ε = 10.8). The lengths of high-impedance parts of the resonator *li*=0.7 mm, their widths W_i=0.5 mm. The widths of low-parts of resonator W_e=1.8 mm. Spacing between the low-impedance parts S_1=0.7 mm. The total lengths of resonators l_r=2 mm. The gap between the open ends of the resonators and the patches *4* S_2=0.38 mm. The dimensions of the low-impedance and high-impedance parts of the HTS element are 1 × 0.6 mm^2 and 0.9 × 0.1 mm^2, respectively. The patch *4* has next sizes 1.7 × 0.65 mm^2. Locations of tapping point (l_c) are chosen from the condition of the maximum return loss in the passband to be -14 dB. The YBaCuO HTS film with thickness 150 nm was deposited on the $NdGaO_3$ substrate having thickness of 0.5 mm. The surface resistance of the film in the normal state is 10 Ω/□. The HTS films were produced by technology as described in [9]. The device was cooled with liquid nitrogen.

Note that the inner dimensions of the device case are 6.3×4.5×7 mm^3.

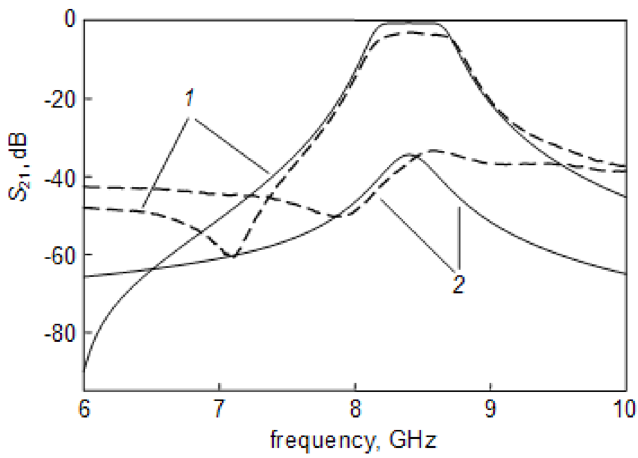

Fig. 3. Frequency response of the power limiter in cases when the HTSC element is in the superconducting (*1*) and the normal state (*2*). The solid curves are the results of electromagnetic simulation; the dashed curves are experimental data.

In Fig.3 the frequency dependences of the transmission coefficient of the simulated and developed prototype of the device are demonstrated. The results were obtained with VNA Rohde&Schwarz ZVL 13. The solid curves are the results of electromagnetic simulation, and the dashed curves show the measured results.

Measuring of the PL's transfer characteristic was performed using the scheme in Fig.2. The measurements were carried out at the temperature of liquid nitrogen, at a frequency 8.3 GHz and their result is presented in Fig. 4.

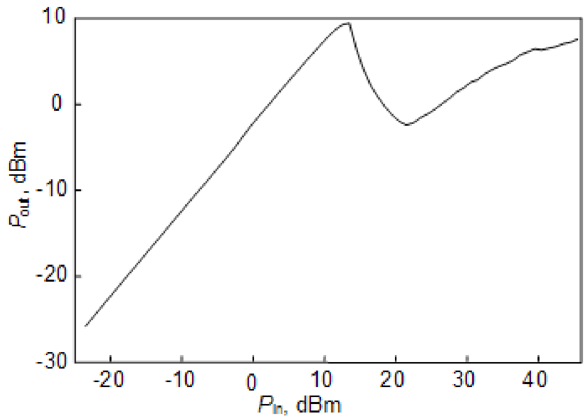

Fig. 4. Transfer characteristics of the fabricated device.

V. Discussion of Results

It can be seen (Fig. 3) that power limiter's fractional width of passband is about 7% with central frequency being equal to 8.3 GHz. The minimum loss in the passband is 3 dB in this case. When the HTS-element passes from superconducting to normal state the transmission coefficient decreases by about 35 dB at the operating frequencies. It means that power of a signal will be attenuated approximately in thousand times. One can see that the simulated results are in good agreement with the data obtained by measuring the experimental prototype of power limiter.

There are some features of the transfer characteristic (Fig.4). In the linear regime the power limiter shows 3 dB insertion loss. Drop in P_{out} occurs when the input power reaches a critical level of P_{in}=13.5 dBm (22.4 mW). When input power further increases P_{out} goes up again, but the slope deviates from the linear regime. The leakage level is found to be 5.9 mW (7.7 dBm) at the input power about 46.5 dBm) (44.6 W). It means that limitation equals 37 dB in this case.

VI. CONCLUSION

A microwave power limiter is presented. The device consists of two microstrip quarter-wave stepped-impedance resonators and the third one which is composite with build-in HTS-element. The prototype of a limiter has operation fractional width 7% with central frequency 8.3 GHz. Transfer characteristic of the device was investigated in the case of microwave power level up to 44 W.

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