AN ACTIVE MICROWAVE FILTER WITH DIELECTRIC RESONATOR

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Abstract

An active microwave filter has been newly developed by using dielectric resonators combined with active elements. The purpose of this paper is to describe about the new technique and the performance of the active filter at 6 GHz band. The value of the equivalent unloaded Q of the resonant element exceeds 37,000 in our experiment.

Introduction

Microstrip line filter which is constructed with dielectric resonators is often used in a microwave frequency region because of its small size and low insertion loss.[1,2] It is reported that the value of the unloaded Q, Q_0, of the dielectric resonator in free space is as large as 7,000 at 6.5 GHz.[3] However, the value of Q_0 of the dielectric resonator mounted on a microstrip line decreases to small value less than 1500 due to the effect of the adjacent conductor. For the practical use, much larger value of Q_0 is necessary to compose a very narrow band filter. In order to increase an equivalent unloaded Q of the resonator, we propose the method of injecting energy to a dielectric resonator from an active element. Since the large value of f_t of the bipolar transistor and of GaAs FET were obtained by recent progress,[4] these could be used as active elements above mentioned.

Here is another point we have to notice: when the loss of the resonator is compensated by active elements, the filter with high Q resonator operates more stably than that with low Q resonator. Combining a dielectric resonator with an active element on the microstrip substrate, we obtained in our experiment, the equivalent unloaded Q as large as 37,000 at 6.5 GHz.

The construction and the equivalent circuit of proposed active filter

1. Band elimination filter (B.E.F.)

The construction and the equivalent circuit of the newly developed B.E.F. are shown in Fig. 1(a) and (b) respectively. In Fig. 1, the field of a dielectric resonator, D, acting on $TE_{01\delta}$ mode is coupled magnetically with the main microstrip line S_0. The field of the dielectric resonator is also coupled with two other microstrip lines S_1 and S_2. S_1 is connected to one port of a bipolar transistor, T, through the line with proper phase, ϕ, and S_2 is connected to the other port of T through an attenuator, A, made of PIN diode.

An equivalent high Q circuit can be realized by injecting proper energy to D from T through a positive feed back loop. Here, it is necessary to adjust the value of ϕ and A. In Fig. 1(b), D is expressed by a series resonant lumped element and a resistive component, R_s. Mutual magnetic coupling coefficients between D and S_0, S_1 and S_2 are defined as M_0, M_1 and M_2 respectively. The equivalent series impedance, R_e, between terminals 1, 1' and 2, 2' can be obtained as eq. (1), where Y is the transmission admittance between terminals 3, 3' and 4, 4', and ω_0 is the center angular frequency.

$$R_e = \frac{(\omega_0 M_0)^2}{R_s - \omega_0^2 M_1 M_2 |Y|} \qquad (1)$$

The attenuation, α, between terminals 1, 1', and 2, 2', can be expressed by eq. (2), where Z_0 is the characteristic impedance of the main microstrip line.

$$\alpha\,[\mathrm{dB}] \simeq 20 \log \frac{(\omega_0 M_0)^2}{Z_0(R_s - \omega_0^2 M_1 M_2 |Y|)} \qquad (2)$$

It is evident from eq. (1) and (2) that the value of R_e and α at ω_0 increase by injecting energy from T to D, in another words, by canceling the dissipative loss of the dielectric resonator.

2. Band pass filter (B.P.F.)

The construction and the equivalent circuit of B.P.F. is shown in Fig. 2(a) and (b), respectively. D and T are coupled in the same way as explained in B.E.F. If we separate the microstrip line, S_0, into an input and output part and then couple these parts with the increased Q resonator magnetically, a very sharp band pass performance can be obtained.

It is well known that the value of Q_0 of the center resonator in three pole B.P.F. has to be larger than others.[5] We propose, therefore, to utilize the above mentioned high Q resonator for the center one as shown in Fig. 3.

Performance of proposed active filter

The experimental results of the frequency characteristics of the single pole active B.E.F. are shown by solid lines in Fig. 4. The center frequency, f_0, is equal to 6.6 GHz and 3 dB bandwidth, Δf is varied by means of distance t between D and S_0, and they are 18, 12.8 and 5.2 MHz according to the values of t in Fig. 4. The value of the attenuation at f_0 is larger than 40 dB, and then the value of the equivalent Q_0 exceeds 37,000. These values have been obtained. The band elimination performance of the passive dielectric resonator mounted on a microstrip is shown by dotted lines in Fig. 4. The initial Q_0 value of the resonator, that is, without positive feedback loop in Fig. 1(a) is about 1500, and therefore it is found that Q_0 increased by about 25 times. Fig. 5 shows the frequency characteristic of single pole active B.P.F. for two values of t. The gain of this active B.P.F. is recognized at the center frequency for a large value of t.

The characteristics of the three pole active B.P.F. in Fig. 3 is shown in Fig. 6. The insertion loss is less than 0.8 dB and the bandwidth is about 12 MHz. Fig. 7 and Fig. 8 show the temperature dependence of B.E.F. and B.P.F. respectively. The values of the attenuation larger than 29 dB are obtained at the center frequency of B.E.F. in the temperature range from 0°C to 40°C. Fig. 8 shows the relation between the temperature and the fluctuation of the insertion loss at the center frequency of B.P.F. for t = 0 as shown in Fig. 5. The fluctuation between 0°C and 40°C ranges within 1.1 dB.

Conclusion

As mentioned above, with injecting energy to the resonator from the active element, the Q_0 value of the dielectric resonator has been increased by 25 times at 6 GHz band. This increased Q resonator can be used to construct the very narrow band elimination filter and the band pass filter.

These filters are expected to be applied to remove an undesired wave or to select a desired wave in such fields of the broadcasting and of the microwave relay system.

References

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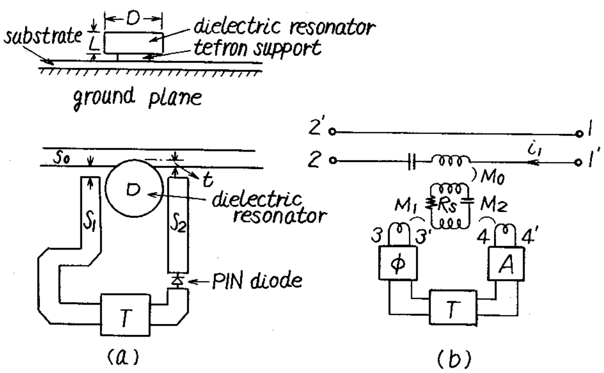

Fig. 1 Construction and equivalent circuit of newly developed band elimination filter

Dielectric resonator	D = 8.8 mm L = 2.8 mm ε_r = 39	
Microstrip substrate	thickness = 1.2 mm ε_r = 2.5	
Height of tefron support = 1.0 mm		

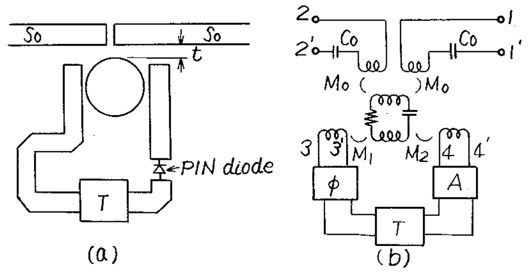

Fig. 2 Construction and equivalent circuit of newly developed band pass filter

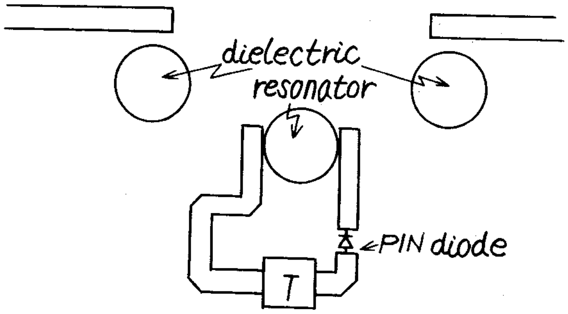

Fig. 3 Construction of three pole band pass filter with active element

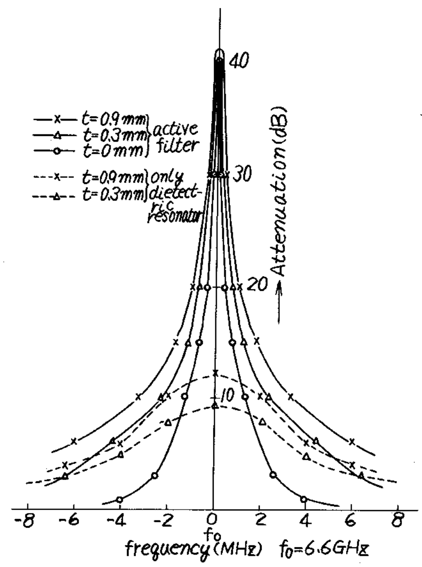

Fig. 4 Frequency characteristics of active band elimination filter

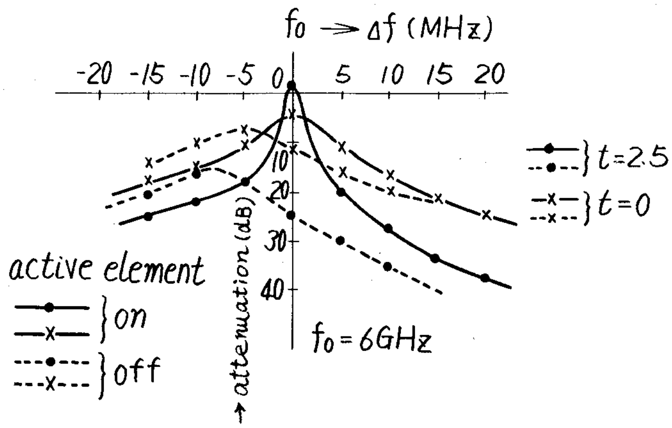

Fig. 5 Frequency characteristics of signal pole B.P.F.

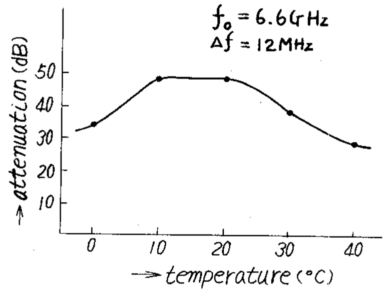

Fig. 7 Temperature dependence of the attenuation at the center frequency of single pole B.E.F.

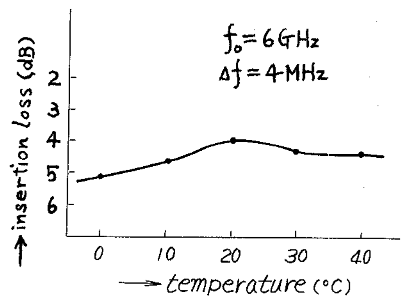

Fig. 8 Fluctuation of the insertion loss at center frequency of single pole B.P.F.

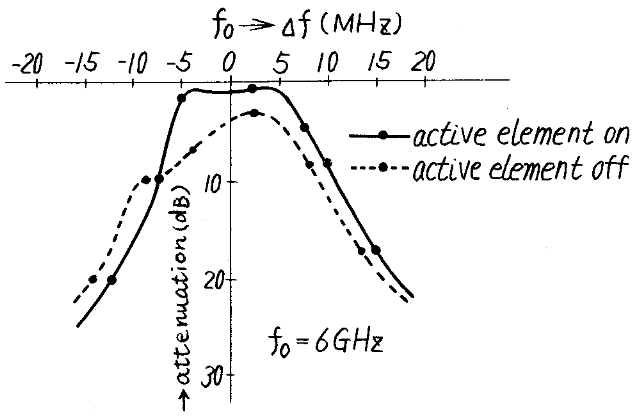

Fig. 6 Frequency characteristics of three pole B.P.F.