DIELECTRIC RECEIVING FILTER WITH SHARP STOP BAND USING ACTIVE FEEDBACK RESONATOR METHOD FOR CELLULAR BASE STATIONS

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ABSTRACT

800MHz band dielectric receiving filter with sharp stopband has been developed. By using the active feedback resonator method, unloaded Q of resonator having 1500 was raised to over 50000. And small size active bandstop filter with high rejection was obtained. Center frequency is 845.75MHz stopband width is 1.0MHz, and attenuation is 30dB. Physical size is 55×180×25mm.

INTRODUCTION

Cellular telephone communications systems have been increasing worldwide, and because of this, the number of base stations for these systems has been increasing rapidly. In the past, we developed transmitter multiplexers which are important parts for base stations. These multiplexers have become smaller and less expensive by using dielectric resonators[1)-3)]

Recently because the frequency band used for communications has been filled with operating frequencies, the extension of frequency bands is requested and more complex frequency allocation is set. The frequency allocation newly released by the FCC is shown in Figure 1. In this case, in order to avoid interference between each service provider, small size bandstop filters which have high rejection in receive frequency bands and low loss in passband are particularly needed. Resonators used for such filters are essentially needed to be small size and to have quite high unloaded Q values. One of the solutions for this problem is the use of an active feedback resonator constructed by a feedback amplifier circuit and a resonator. We call this AFR. But in general the electrical characteristics of AFR are unstable and the consideration for noise figure have been insufficient[4),5)]

By improving the stability of AFR and considering noise figure, we have developed a new active bandstop filter with sharp stopband. The basic resonator is a coaxial TEM mode dielectric resonator, and unloaded Q of AFR is raised from 1500 to 50000. By combining this filter with the usual receiving antenna filter, we have obtained bandpass characteristics with sharp stopband in passband.

In this paper we will further describe AFR and the active bandstop filter.

PRINCIPLE AND CONSTRUCTION OF ACTIVE FEEDBACK RESONATOR

Principle

The equivalent circuit of an active feedback resonator (AFR) is shown in Figure 2. AFR is constructed by the basic resonator and the feedback amplifier circuit. For the basic resonator, in view of size and unloaded Q, the dielectric resonator is to be used. The feedback amplifier circuit is coupled to the basic resonator and compensates power loss in this resonator. Consequently unloaded Q of AFR is raised a great deal. The value of unloaded Q of AFR is calculated by the following equation.

$$Qo = \frac{Qoo}{[1+2(Qoo/Qei)][1-A(Qoo/Qei)\cos\theta]}$$

Qoo:unloaded Q of basic resonator
Qei:external Q to feedback amp. circuit
A :gain of feedback amp. circuit
θ :phase delay of feedback amp. circuit

Relation between gain of feedback amplifier circuit and unloaded Q is shown in Figure 3. In this case the phase delay of the feedback amplifier circuit is $2n\pi$,

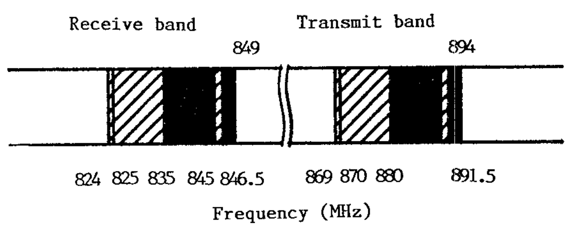

Fig. 1 Frequency allocation

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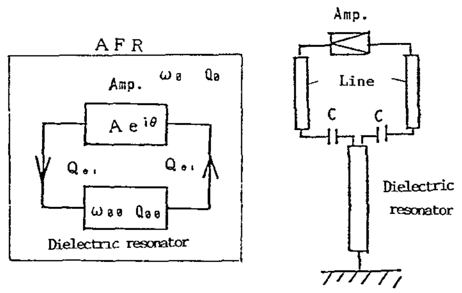

Fig. 2 Equivalent circuit of AFR

unloaded Q of AFR is raised to infinity at the lowest gain. If gain is more than this value, the unloaded Q is negative and AFR oscillates.

The difference of the performance of AFR between when the feedback amplifier operates and when it does not operate is shown in Figure 4. By using AFR, a great deal of the volume reduction is possible. When the raising rate of unloaded Q is 10, the reduction rate of the volume is 100.

When the feedback amplifier operates, the resonant frequency of AFR varies a little. The value of the resonant frequency is calculated by the following equation.

$$\Delta\omega\cdot Q_0 = \frac{A(Qoo/Qei)\sin\theta}{1-A(Qoo/Qei)\cos\theta} \qquad \Delta\omega = \omega_0/\omega_{00} - \omega_{00}/\omega_0$$

By using this equation, the exact design of AFR becomes possible.

The stability is calculated by differentiating the above equations. The stable condition is as follows.

$$2AQoo^2\cos\theta = QoQei$$

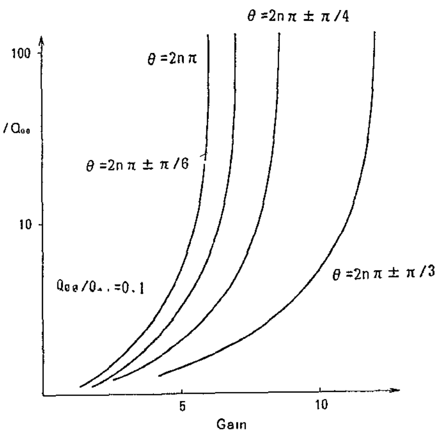

Fig. 3 Unloaded Q of AFR

Basic construction of AFR

The basic circuit of AFR we used is shown in Figure 5. The basic resonator is a TEM mode quarter wavelength coaxial dielectric resonator. The dielectric material is shown in Table 1. The conductor of the electrode is fired silver. The feedback amplifier circuit is the microstrip circuit which is constructed on the printed circuit board by using a photo etching technique, and which is coupled to the inner conductor of the open side of the basic resonator. The transistor used in the feedback amplifier circuit is Si bipolar, having low noise and high gain.

Table 1. Dielectoric material

Material system	$MgTiO_3$-$CaTiO_3$
Dielectric permittivity	21
Dissipation factor	5.0×10^{-5}(800MHz)
Temperature coefiicient	+3 ppm/°C

CONSTRUCTION AND DESIGN OF ACTIVE BANDSTOP FILTER

Construction

The construction of the active bandstop filter using AFR is shown in Figure 6. The case is made of blass, and the input, output, DC terminals are N type and SMA type connectors and fixed on the case. These terminals are adequately isolated from each other. The signal flow line is the 50 ohm microstripline using high K dielectric substrate. AFRs are connected to this line as high Q trap resonators, and arrayed at intervals of one quarter of the wavelength. Each AFR is shielded individually by a metal plate.

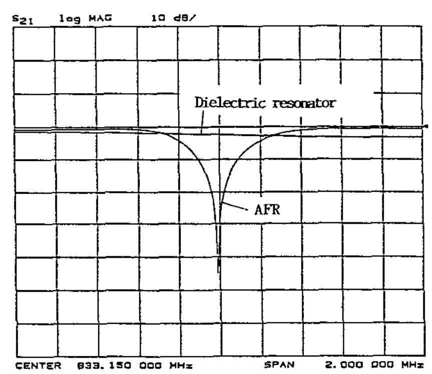

Fig. 4 Performance of AFR and dielectoric resonator

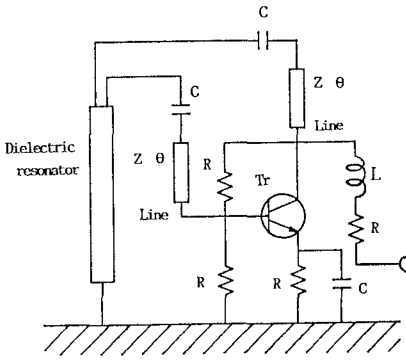

Fig. 5 Basic circuit of AFR

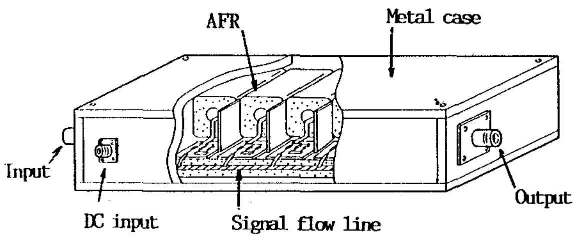

Fig. 6 Basic construction of filter

Filter design

The equivalent circuit of active bandstop filter is shown in Figure 7. The filter type is the distributed bandstop filter, and the design parameter values are calculated by usual Chebysheff chacterzation design method. The resonant frequencies of basic dielectric resonators in AFRs are determined in consideration of deviations of resonant frequencies by the coupling to the feedback amplifier circuit. Usually phase delay of the feedback amplifier circuit id chosen to be within $2\pi+\pi/10$ for the reason of the power and temperature stability, the deviation of resonant frequencies is limited within 1.0MHz. Unloaded Q of the basic resonator is practically needed to be more than 1/100 of AFR for the reason of stability. Unloaded Q of the basic dielectric resonator we used is about 1500, the deviation of resonant frequencies is held within 30 KHz at 0~60°C in power level lower than 0 dBm.

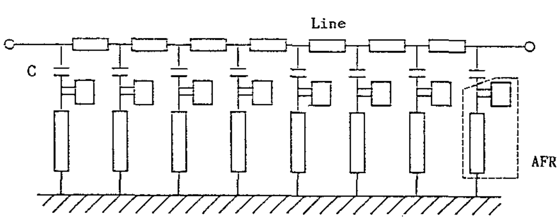

Fig. 7 Equivalent circuit of active bandstop filter

Noise figure

For active circuits, the noise figure is one of the most important electrical characteristics. When a trap filter is constructed by AFR and a coupling capacitor noise figure of the trap filter is calculated by the following equation.

$$N.F.=N.F._{Tr.}\frac{AB}{1-AB} \quad B=\frac{(2/Q_{ei})^2}{(2/Q_e+1/Q_{co}+2/Q_{ei})^2+(\Delta\omega)^2}$$

Qe:external Q

At the reasonant frequency, the noise figure becomes its maximum value. But comparing with the case of an usual amplifier circuit, this value is smaller, particularly sufficient in passband. An example of noise figure characteristics is shown in Figure 8. In case input power level is less than 0 dBm, noise power generating in AFR is negligibly small. This is one of the advantageous points.

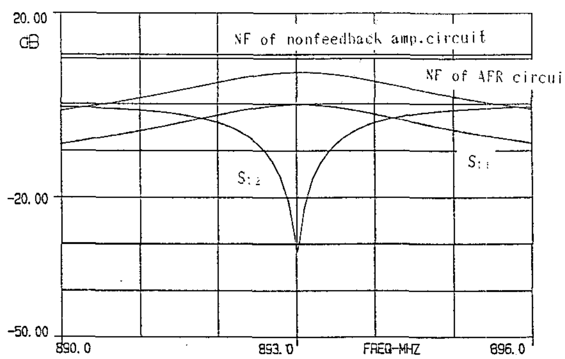

Fig. 8 Noise figure

PERFORMANCE

We made the 8-pole active bandstop filter using AFR. The performance of this filter is shown in Table 2. Center frequency is

Table 2. Performance

Number of section	8
Center frequency	845.75 MHz
Stopband width	1.0 MHz
Attenuation	30 dB
Insertion loss (f ±1.25MHz)	0.7 db
Return loss (f±1.25MHz)	15 dB
Input power	0 dBm Max.
DC power	250 mW Max.
Physical size	55×180×25 mm

845.75MHz, and bandwidth is 1.0MHz. The electrical characteristics are shown in Figures 9 and 10. A very sharp bandstop characteristic curve was obtained. Unloaded Q of AFR is more than 50000. An outside view of this filter is shown in Figure 12. Physical size is 55×180×25mm.

Furthermore we combined this filter with the usual dielectric receiving antenna filter in cascade, and after adjusting the phase delay between these filters the attenuation characteristics shown in Figure 11 was obtained. The new characteristic curve having sharp stopband in passband was found. By using this filter as the receiving filter for extended cellular systems, unwanted signals in passband can be rejected effectively.

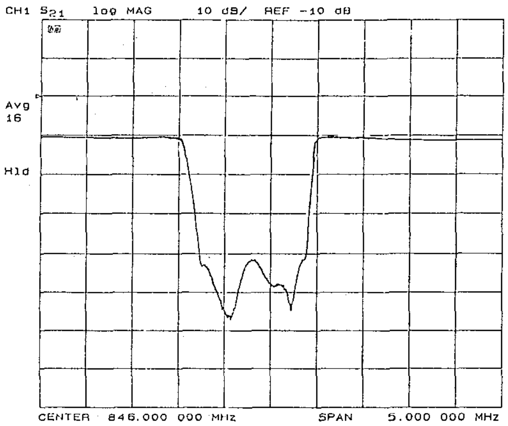

Fig. 9 Attenuation characteristics

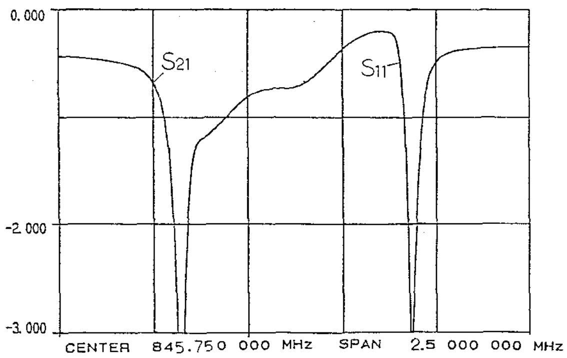

Fig. 10 Insertion loss and return loss characteristics

CONCLUSION

We have developed 800MHz band dielectric receiving filter with sharp stopband by using the active feedback resonator (AFR) method. We considered the principle of AFR, and showed equations for raising unloaded Q and deviation of resonant frequency. A TEM mode dielectric resonator is used as the basic resonator of AFR, of which unloaded Q is raised from 1500 to 50000. Noise power generating in AFR in passband is sufficiently small. The active bandstop filter is small and has high rejection characteristics, stopband width is 1.0 MHz, attenuation is 30dB, and physical size is 55×180×25mm. This filter is useful as the receiving antenna filter of cellular base stations.

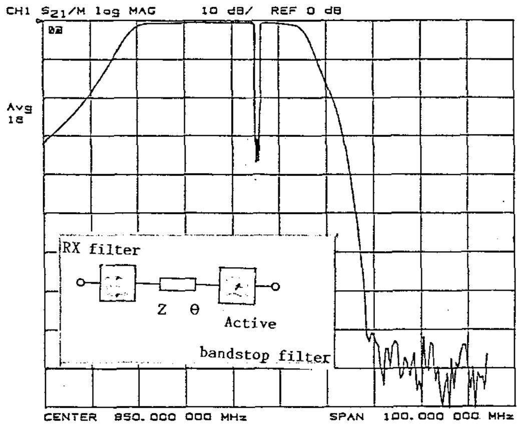

Fig. 11 Attenuation characteristics of combined receiving filter

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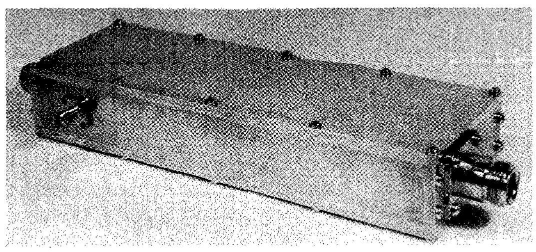

Fig. 12 Outside view of active bandstop filter