Advanced Materials '93, I / B: Magnetic, Fullerene, Dielectric, Ferroelectric,
Diamond and Related Materials, edited by M. Homma et al.
Trans. Mat. Res. Soc. Jpn., Volume 14B

Miniaturized low-loss dielectric filter for mobile radio using a quasi-microwave band

F. Mizuno, K. Ito, M. Ogawa, and K. Ohya

NTK Piezoelectric Ceramics Division, NGK Spark Plug Co., Ltd.,
14-18 Takatsuji-cho, Mizuho-ku, Nagoya 467, Japan

The design of a miniature narrow-band filter made of microwave dielectrics for 1.9 GHz is discussed. The new construction method of our designed dielectric filters, which combines interdigital stripline resonator with TEM coaxial resonator, is proposed with a microwave dielectric ceramics of high permittivity of ε_r=81. These filters are also considered to be applicable to portable radio telephone terminals for next digital modulation system of JDC at 1.5 GHz band.

1. INTRODUCTION

It has been planned that the next generation of the mobile communication systems put into practical use at quasi-microwave band as well as the change from analog to digital modulation method.

In terms of physical size and cost reduction, both the antenna top filter and RF interstage filter are most important as an RF passive components. The filter using the dielectric resonator has the biggest advantage for the reduction of cost and physical size. These dielectric filters can be of several different designs[1]. The filters may, for example, be made of discrete cavities such as λ/4-coaxial ceramic resonators coupled to each other by external capacitors.

In this report, the construction, design method, and characteristics of the new type of miniaturized dielectric filter are discussed.

2. CONSTRUCTION

The appearance of the filter is shown in Figure 1. It is constructed by both microstripline resonator and TEM coaxial resonator as a fundamental elements. Its two dielectric elements, above and below, are made of high permittivity ceramics of ε_r=81. One element with electrodes of both ground and interdigital stripline pattern is drawn by painting of thick film with miniaturized and light-weight characteristics. The other element is of TEM coaxial resonator with high-Q characteristics.

As this type of filter is interdigital λ/4-stripline resonator, the resonators can be directly coupled each other with odd and even mode of electric field. In this case, the coupling coefficient of k is expressed by equation (1).

$$k=2|\omega_{re}-\omega_{ro}|/(\omega_{re}+\omega_{ro}), \quad (1)$$

where ω_{re} and ω_{ro} are even and odd resonant angular frequencies, respectively[1]. In the case of using high permittivity material as a TEM resonator, because the whole characteristic impedance of Z_0 is very small, the mutual coupling of each resonator is extremely strong. Therefore, the band width of the interdigital filter may be very wide.

This new kind of narrow band filter is realized by decreasing the coupling coefficient without making the length between resonators larger, because the metalized groove is provided in the position of the symmetrical face of each resonator, where the maximum electric field of odd mode is achieved as

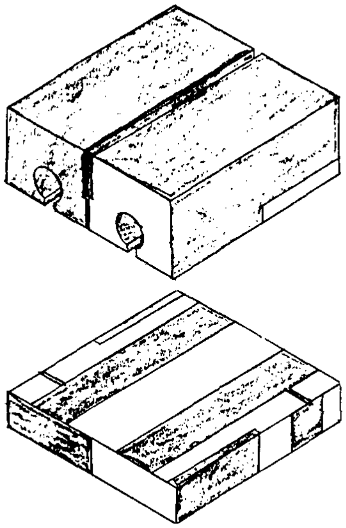
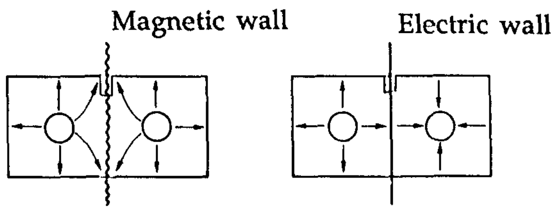


Figure 1. Basic construction.



(a) odd mode (b) even mode

Figure 2. Elctric field distribution of coaxial resonator.

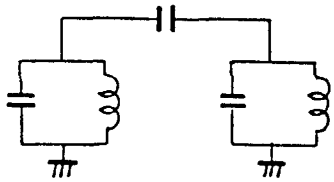


Figure 3. Equivalent circuit simulated to combline filter.

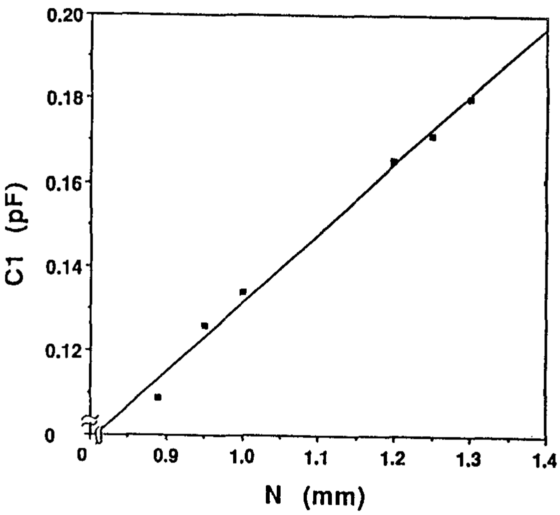


Figure 4. The relationship between interstage capacitance of C1 and the rest dielectric length of N in the groove.

shown in Figure 2. Thus the coupling coefficient can be adjusted by changing the width and depth of the groove.

It is generally known that the conductive loss of plannar stripline increases, compared with that of TEM coaxial line, because the surface area of the stripline decreases to $1/\pi$ of that of TEM coaxial line in the case of the same diameter as the width of the stripline [2]. Therefore, there is such a major fault as large insertion loss in the stripline filter[3]. In order to improve the insertion loss, suitable ratio of outer and inner diameter is chosen in the upper element[4]. As this construction softens the current density concentration on the edge of the striplines, the unloaded Q of the filter can be improved. Therefore, the insertion loss may be extremely smaller.

This filter is soldered in several points. Input, output, and ground parts are designed to be suitable for face-bonding and can be soldered easily on printed circuit boards.

3. DESIGN

The equivalent circuit used in the simulated calculation for 2-pole band pass filter is shown in Figure 3. As a parameter, the length of stripline, the input and output position by inductive coupling, and the width and depth of groove are chosen. The simulation data

Table 1
Electric properties for antenna top filter

	Required	Result
Physical size	——	5.8 x 4.4 x 3.0mm
Center frequency	1.901 GHz	1.901 GHz
Band width at 0.8 dB	12 MHz	12.6 MHz
Insertion loss	0.7 dB	0.7 dB(Top)
Reflection loss	18 dB	17 dB
Attenuation at f_0-240 MHz	31.0 dB	31.0 dB
Attenuation at f_0-480 MHz	75.5 dB	72.0 dB

Table 2
Electric properties for antenna top filter

	Required	Result
→		5.8 x 4.4 x 3.0mm
→	1.901 GHz	1.901 GHz
Band width at 1.2 dB	12 MHz	13.6 MHz
→	1.0 dB	1.0 dB(Top)
→	18 dB	17 dB
→	37.0 dB	35.5 dB
→	78.5 dB	75.0 dB

changing these parameters were useful for the desired design calculation. In the simulation data, input and output coupling and interstage coupling were approximated to be inductive and capacitive, respectively.

The relationship between interstage capacitance and the rest dielectric length of N in the groove region is shown in Figure 4. The measured capacitance can be approximated to increase straightforward with increasing N.

4. ELECTRIC PROPERTIES

The electric properties of these two types of filters are shown with design object in both Table 1 and 2. The performance satisfies the requirements shown in Table 1 and 2. The Q_0 of resonators is about 300, and insertion loss of antenna top and RF interstage filters were 0.7 and 1.0 dB, respectively. Though the attenuation curve at lower and higher frequencies is slightly more gentle, compared with that dotted calculated data, it is confirmed that the frequency characteristics is in good agreement with that of the simulation data by equivalent circuit as shown in Figure 5. The attenuation at f_0-240 MHz in top and interstage filters were 30 and 35 dB, respectively.

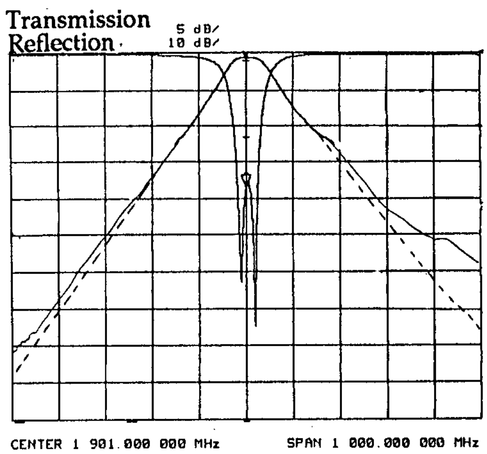


Figure 5. Attenuation and return loss characteristics.

By narrowing band design technique, construction outer dimensions are 5.8x4.4x2.9 mm and 0.075 cm^3, respectively.

The deviation of the resonant frequency was within 1 MHz in the range from -40 to 85 °C, and this result agrees well with the temperature stability of the microwave dielectric ceramics. The reflection loss in the pass band region was about 15 dB.

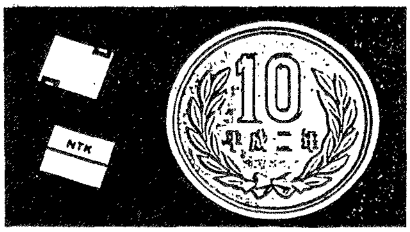


Figure 6. Face-bonding dielectric filter.

5. CONCLUSION

The new construction method of our designed dielectric filters, which combines interdigital stripline resonator with TEM coaxial resonator was developed with a microwave dielectric ceramics of high permittivity.

This filter is small, about 1/2 the size of conventional TEM coaxial filter. Additionally, the filter can be mounted c printed circuit boards by using face-bondir technique. In electric properties, comparε with the microstripline filter, insertion loss improved about 20 %, and RF leakage almost suppressed. This mass producible, co reduction filter is also consideded to t applicable to portable radio telephor terminals for next digital modulation systen of JDC at 1.5 GHz band.

REFERENCES

1. G. Matthaei, L. Young, E. M. T. Jone Impedance Matching Networks an Coupling Structures, Artech House Inc., 198
2. I. A. G. Malherbe, Microwave Transmissio Line Filters, Artech House Inc., 1979.
3. M. Dishal, IEEE MTT-13, No. 5 (1965) 696.
4. M. Dishal, IRE (1951) 1448.