Recent Dielectric Filter Technology
And Relationship with SAW Technology in the Future

Jun Hattori

Murata Manufacturing Company, Ltd.
Development Department 1, Development Group 4, R & D Division
Tenjin 2-26-10, Nagaokakyo, Kyoto, Japan
Tel: 075-955-6758, E-mail: jhattori@murata.co.jp

Abstract - This paper describes recent dielectric filter technologies[2][3], at first, which are mainly utilized for mobile wireless telecommunication systems. It contains coaxial resonator filter, mono block type filter, multi layer type filter and TM-TE mode type filters, all of which are made of high K ceramic dielectric material. These have good electrical performances and have been in practical use for cellular handset and base station at 900MHz and 2GHz band, but have certain limitation in size and weight reduction. SAW technology is so powerful as to solve this problem but not almighty. This paper secondly describes comparison between SAW and dielectric filter technologies and make clear what are essentially advantageous and not for each technology. And for the future, the possibility of technically combined novel filter architecture is discussed. In order to realize it, dielectric filter technology itself have to be renovated. As one of solutions, the new dielectric planar filter technology utilizing thin film electrode is introduced. That has very small size and flat shape, so matches well to SAW architecture. As examples, a new 26GHz planar bandpass filters and thin film electrode and a new 2GHz band elimination filter using TFLE(Tin Film Layered Electrode) technology are introduced.

1. INTRODUCTION

The dielectric filter technology based on high K ceramic material has been contributing great size reduction of a mobile telecommunication equipment, especially cellular handset and base station. That is superior in electrical performances and reliability. Furthermore it has good mass productivity and low cost. But for the next 3'rd generation of CDMA, the filter is required to become more compact and more functional strongly. As one of solutions to respond it, SAW technology has become more powerful and been spread worldwide. But SAW technology has some disadvantageous points which are high power capability and limited applicable frequency range for example. In order to solve this problem, a novel technology has to be developed by combination that compensate each other. And at the same time, dielectric filter technology have to be evolved. Thin film electrode technology is succeeding the advantage of ceramic filter (high unloaded Q, excellent temperature stability, wide bandwidth and high power operability). In this paper, the features and some kinds of dielectric filter technologies and comparison and fusion with SAW technology are explained.
2. COAXIAL DIELECTRIC FILTER
Coaxial dielectric filter is the most popular and commercially successful technology. Resonant mode is TEM, and the resonator length is shortened proportional to inverse of square root of dielectric constant. Conventionally a filter has been made of some gathered individual resonators, but recently mono block ceramic type became common technology. Fig. 1 shows the structure of coaxial dielectric resonators. And as an improved version, step impedance structure that has step wise large inner hole diameter near open end has been developed and contributes to further size reduction. Coaxial filter has been used mainly for handset of cellular system, now is the standard technology. Fig. 2 shows an example of size and electrical characteristics of coaxial type duplexer. The features of this technology are high unloaded Q, good high power performance, flexible design capability, good mass productivity and low cost. The problems are further size reduction, lower profile and lighter weight.

3. MULTILAYER CERAMIC FILTER
Multi layer ceramic filter technology is based on monolithic ceramic capacitor production technology, and filter is made by co-firing multi alternately layered ceramic sheets and pattern electrodes. Resonator type is basically same as stripline type or lumped element type, and resonant mode is TEM or parallel LC. Fig. 3 shows the structure of this filter. Unloaded Q and power performance is inferior to coaxial type, but design flexibility is excellent and cost is very low. It is used mainly as inter, stage filter of cellular handset. The noteworthy advantage is, that it can include and integrate some additional functions, for example couplers, capacitors, resistors, chip IC’s, SAW devices, so this is very useful for RF module. Fig. 4 shows size and electrical performance of such filter. Fig. 5 shows a example of integrated module.

![Fig.1 Structure of coaxial resonators](image)

![Fig.2 1.9GHz bandpass filter](image)

![Fig.3 Structure of multilayer resonators](image)

![Fig.4 1.9GHz interstage bandpass filter](image)
4. DIELECTRIC HIGH POWER FILTER[6]

For antenna filter used for cellular base station, high power handling capability is requested essentially, and conventionally air cavity type has been used for it. But in order to reduce size and cost, dielectric high power filter has been started to be adopted. Resonant mode of dielectric resonator is TE or TM mode. TE$_{01}$ mode is most orthodox and has high unloaded Q, but size is very large. On the other hand TM mode has suitable size and unloaded Q, but had been difficult to be constructed. But now by developing mono block TM mode resonator, high power TM mode filter has been in practical use. Furthermore in order to reduce size, dual and triple mode technology is developed, technology is now progressing rapidly. Fig. 6 shows the structure of a TM triple mode resonator and TE-TM triple mode resonator. The features are small size, high unloaded Q, good high power performance and good design flexibility. Fig. 7 shows view and electrical performance of duplexer for 2GHz band base station, that is suitable for W-CDMA cellular system application.

5. PLANAR MILLIMETER WAVE FILTER[4]

Most current mobile telecomm systems use up to 5GHz band. But to realize faster and higher capacity data transmission, millimeter wave system has been investigated and partially put into practical use. In millimeter wave band conventionally waveguide type filter has been used, but recently for size and cost reduction new dielectric planar type filter has been developed.

Fig. 8 shows the structure of Planar Thin film TE mode Dielectric Resonator (PTDR). The PTDR has multi layer structure which consists of a high K substrate and thin-film electrodes on
both sides. The volume of the PTDR is less than 1/10 of the waveguide filter. The configuration and electrical performance of the 26GHz band duplexer are shown in Fig. 9. The PTDRs were fabricated by using photolithography technique, and it realize excellent mass-productivity. The dimensions of the diplexer are 8 mm × 42mm × 3.5 mm.

6. DIELECTRIC FILTER TECHNOLOGY AND SAW FILTER TECHNOLOGY

The technology comparison between dielectric filter and SAW filter is shown in Table 1. Items of comparison are electrical performances (insertion loss, fractional bandwidth, spurious response), handling power and intermodulation, size and weight, temperature stability, design flexibility, cost (mass productivity). SAW filter is superior in spurious response, size, weight, especially, but inferior in fractional bandwidth, frequency range and high handling power. On the other hand, dielectric filter is superior in insertion loss, fractional bandwidth, handling power, intermodulation and temperature performance, but inferior in spurious response, size, and weight. Those features are due to physical nature. As a result, now we have not almighty technology, each technology may be compensative with each other. Commercially speaking, SAW is suitable for less than 1 GHz low power application, for example 900MHz band cellular handset filter. Dielectric filter is suitable for more than 2 GHz high power application, for example millimeter wave filter and cellular base station filter. But in overlapping region, for example 2GHz band handset filter, the method to gain the most practical and powerful solution must be combination and fusion of these technologies. Now what is required strongly for dielectric filter is the breakthrough to the new technology suitable for combining with SAW technology. As a candidate of novel dielectric technologies, planar dielectric filter utilizing thin film electrode is introduced.
<table>
<thead>
<tr>
<th>Performance Comparison</th>
<th>Dielectric Filter (2GHz)</th>
<th>SAW Filter (2GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion Loss</td>
<td>Low (&lt;1.8dB)</td>
<td>Medium (&lt;2.5dB)</td>
</tr>
<tr>
<td>Fractional Band Width</td>
<td>Wide (&lt;10%)</td>
<td>Medium (&lt;3%)</td>
</tr>
<tr>
<td>Frequency Range</td>
<td>Wide (&lt;10G)</td>
<td>Medium (&lt;3G)</td>
</tr>
<tr>
<td>Spurious Response</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>Handling Power</td>
<td>High (&lt;200W)</td>
<td>Low (&lt;0.3W)</td>
</tr>
<tr>
<td>IM (Inter-Modulation)</td>
<td>Excellent</td>
<td>Fair</td>
</tr>
<tr>
<td>Size</td>
<td>Medium</td>
<td>Small</td>
</tr>
<tr>
<td>Weight</td>
<td>A little Heavy</td>
<td>Light</td>
</tr>
<tr>
<td>Temperature Performance</td>
<td>Stable (0-5ppm)</td>
<td>Unstable (-20-90ppm)</td>
</tr>
<tr>
<td>Impedance Matching</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Design Flexibility</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Cost</td>
<td>Low</td>
<td>Medium</td>
</tr>
</tbody>
</table>

7. A NEW DIELECTRIC FILTER TECHNOLOGY UTILIZING THIN FILM ELECTRODE

A Poreless Ceramic Substrate[1]

In order to construct sufficiently qualified thin film electrode, the dielectric ceramic plate that is basis of putting electrode is required to have good surface quality. The new poreless ceramic substrate is obtained by decreasing impure mixed material, realizing fine, uniformly distributed slurry, reducing pore diameter and optimizing burning profile and atmosphere. Fig. 10 shows a transparent poreless ceramic substrate.

![Fig. 10 Poreless ceramic substrate](image)

B TFLE Technology and Application[5]

Energy loss of dielectric resonator can be classified into a conductor loss and a dielectric loss. The conductor loss is due to the current density that concentrates on the conductor surface. TFLE (Thin Film Layered Electrode) technology can solve this problem. The TFLE is stacked alternately by a conductor layer and a dielectric layer on a dielectric substrate. The TFLE is applied to the TM010 mode disk resonator. The structure and electromagnetic mode of the TM010 disk resonator and current distribution in the TFLE is shown in Fig. 11. The rising ratio of conductor Q is in proportion to the square root of the number of conductor layers in comparison with a the conductor Q of a bulk metal.

As one of applications, low profile band elimination filter (BEF) for 2GHz. It is composed of two TM010 mode disk resonators as shown in Fig. 12. The resonator size is \(28.5 \times 5.0\)mm with the unloaded Q of 5,000. The measured data of BEF is shown in Fig. 12.

As further application that can coexist with SAW chip devices, multi-spiral resonator structure is proposed. This is one of modified open ended TM010 mode resonator, flat and uniform electrode is cut into a lot of very fine lines in the direction of radiation, and further these lines are wound in spiral. Unloaded \(Q_0\) decreases at certain rate, but radius of the resonator decreases drastically. For example, the resonator having size of \(2\times2\times0.6\)mm has \(Q_0\) of more than 200 at 2GHz band. Fig. 11 shows the basic configuration of it. The technical problem is how the narrow and high aspect lines are constructed.
8. CONCLUSION

Filters used for mobile telecommunication systems has been and will be required smaller size and higher performance. Firstly the dielectric filter technologies containing coaxial type, multi layer type, TM-TE mode type and millimeter wave type are introduced. In it technical features, main application, an example are explained. Secondly comparison between dielectric filter technology and SAW filter technology is discussed. In it advantages of each technology are made clear. Lastly a novel thin film electrode dielectric filter technology is proposed. That may be coexisting and will be harmonized with SAW technology in the future. And dielectric filter technology will be growing up more than ever. Especially, for use of high power, wide band and high frequency operation, dielectric filter technology will be kept as the most powerful technology.

Acknowledgment

The author thanks deeply to Dr. Y. Ishikawa of Murata Manufacturing Co. for invaluable help and advice regarding whole dielectric filter technology.

REFERENCES