800MHz HIGH POWER DUPLEXER USING TM DUAL MODE DIELECTRIC RESONATORS

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ABSTRACT

A novel small sized high power duplexer in 800 MHz band has been developed by using whole monoblock TM_{110} dual mode dielectric resonators. Insertion loss is less than 0.35 dB over 20 MHz bandwidth in TX filter, and less than 0.47 dB over 40 MHz bandwidth in RX filter. Volume is less than 3000 cm^3 which corresponds to about 20% of re–entrant cavity resonator filter. This duplexer is useful for current and future cellular base stations.

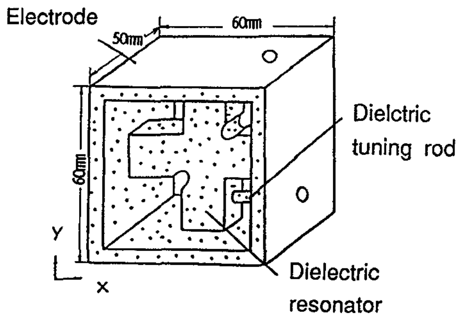
INTRODUCTION

Cellular mobile telecommunication systems are expanding rapidly worldwide. For the base station equipments of these systems, a TM mode dielectric resonator filter was proposed. We have newly developed high power duplexer using dielectric resonators. The duplexer is small in size and highly efficient for FDMA cellular systems. High *K* ceramic materials are used for the dielectric resonators. Some of these filters are already in actual operation since several years. For an equipment of earth station in 4 GHz band satellite systems, a technique was developed to realize TM_{110} dual mode dielectric resonator physically coupled in orthogonal manner. This resonator has physically coupling system in orthogonal manner, which is called Asymmetric Orthogonal Dielectric Resonator(**ASODR**). A 4–section miniaturized dielectric filter was realized by adopting this technique.

Now a concept of microcell has been introduced, and the physical size of the base station equipment needs to be smaller than ever. To meet this tendency, much smaller, effective, more cost reduced, and high reliable filter is required. Two new techniques are proposed here to offer a solution to these issues. The first is to form a monoblock type TM dual mode dielectric resonator in 800 MHz band. The other is to use full monoblock type ASODRs to recline filters. By making the best use of these techniques, a new smaller sized 800 MHz band high power, high performance duplexer was developed for cellular base stations. In this paper firstly the electrical performance and construction of 800 MHz band TM_{110} dual mode resonators are described. Secondly, construction, design and performance of the duplexer are described.

CONSTRUCTION OF TM_{110} DUAL MODE RESONATOR

A full monoblock type TM_{110} dual mode resonator in 800 MHz band was newly developed whose basic construction is shown in Fig.1. Dielectric material is (Zr·Sn)TiO4 with dielectric constant of 38, dielectric losstangent of 4.0×10^{-5} at 800MHz, and temperature coefficient of about 0.6ppm/°C. The posts and frames of TM_{110} dielectric resonator are formed in full monoblock, a particular feature improved from the former vintage of ASODR applied in 4 GHz band. The electrode on the outer shell is fired silver. The resonant frequency is tuned by high K dielectric rod very easily and linearly. Coupling constant is controlled by the design of shape and volume of removed dielectric. The ASODR in 800 MHz band has outer dimension of 60×60×50 mm, and unloaded Q of about 7000. Dielectric frames has little influence on electrical performances, evidenced by the deviation of the resonant frequency of less than 2 %, and the degradation of unloaded Q of less than 7 %. The usual problem of contacting dielectric resonator post with the metal frames is solved by this full monoblock construction.



Material System ;$(Zr{\cdot}Sn)TiO_4$
Dielectric Constant ; $K = 38$
Dielectric loss tangent ; $\tan\delta = 2.5\times10^{-5}$

Fig.1 Basic Construction of TM_{110} Dual Mode Resonator

ELECTRICAL PERFORMANCE OF TM_{110} DUAL MODE RESONATOR

Electric filed distribution of asymmetrically

CH3141-9/92/0000-1617$01.00 © 1992 IEEE

constructed orthogonal TM_{110} dual mode is shown in Fig.2. The dielectric posts are partially removed at the overlapped cross junction. This asymmetric construction creates electrical perturbation between the two modes. Two resonant frequencies created are called f_{even} and f_{odd}, whereas f_{odd} is higher than f_{even}. Comparing with single mode TM_{110} dielectric resonator, degradation of unloaded Q is less than 5%. One of the Advantages of ASODR is that degradation of unloaded Q is small enough to neglect in changing coupling coefficient (k), this a large k can be realized. In the case of ASODR maximum k can be more than 10% and the deviation of Q is less than 8%. The k value can be controlled easily and stably by changing depth of removed dielectrics at the cross junction.

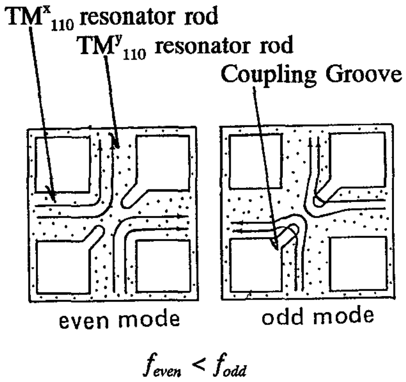


Fig.2 Electric Field Distribution of Asymmetrically Constructed Orthogonal TM_{110} Dual Mode Resonator

HIGH POWER DESIGN OF TM_{110} DUAL MODE RESONATOR

The electric field and current distribution in the dielectric TM_{110} dual mode resonator are shown in Fig.3. The electric field amplitude distribution shows highest peak at the center of dielectric resonator posts, and current amplitude distribution appears near the surroundings of dielectric resonator posts. When a high power bandpass filter in 800 MHz band having 6 poles and bandwidth ratio of 3 % is designed by using this resonator with input power of 60 W, the highest value of electric field amplitude is calculated to about 20 V/mm and the highest value of current density is calculated to about 17 A/mm^2 by FEM numerical analysis.

Under this condition, temperature distribution in the resonator is shown in Fig.4. Temperature rise is less than 12 degree, degradation of unloaded Q is less than 2 % and resonant frequency shift is less than 10 kHz. This degradation as filter characteristics is minimal. The third order intermodulation distortion power level is less than –150 dBc, when two signals of different frequencies have power level of 30 W which proves to cause no sensitivity problems.

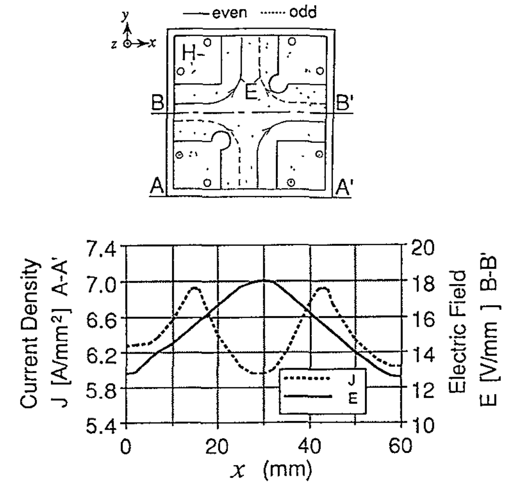


Fig.3 Current Density and Electric Field Distribution in the Dielectric TM_{110} Dual Mode Resonator

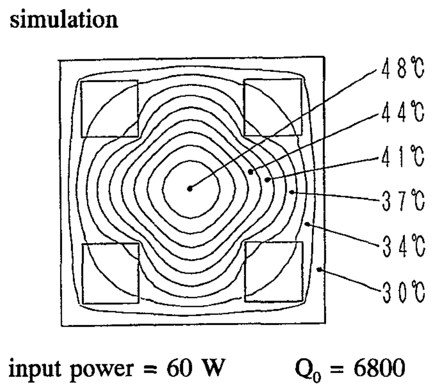


Fig.4 Temperature Distribution in the Resonator

DUPLEXER DESIGN

An equivalent circuit of the duplexer filter is shown in Fig.5. For TX and RX filter parts, coupling between resonators and external loads of input and output are realized by means of coupling coils. Filter design parameters are determined by conventional passband Tchebysheff characteristics design technique. Resonant frequency of is tuned by inserting dielectric tuning rod. Tuning range is about 8 MHz, and frequency shift is proportional to insertion length, consequently tuning is very easy. Unloaded Q of the resonator is not degraded by tuning operations. Since coupling between resonators are precisely designed, coupling constant requires adjustment.

When we make up a duplexer to combine TX and

RX filter. A new duplexing design was employed to make up a duplexer to combine TX and RX filters. In order to realize required external Q and reflection phase at passband each other, shape and size of a few coupling proves can be adjusted, this transmission lines are adequately shortened and size of duplexing construction is greatly reduced. Fig.6 shows relation between inductance of loop prove and external Q. In this case, by using loop which have inductance of more than 15 nH, transmission lines are shprtened to less than 20 mm. Comparing with the cavity type duplexer, control range is wider and linearity is better.

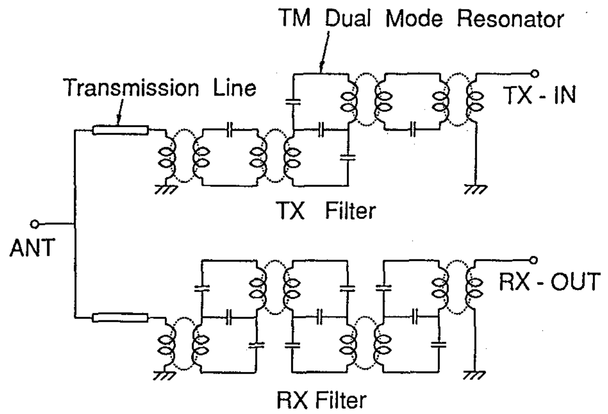


Fig.5 Equivalent Circuit of the Duplexer

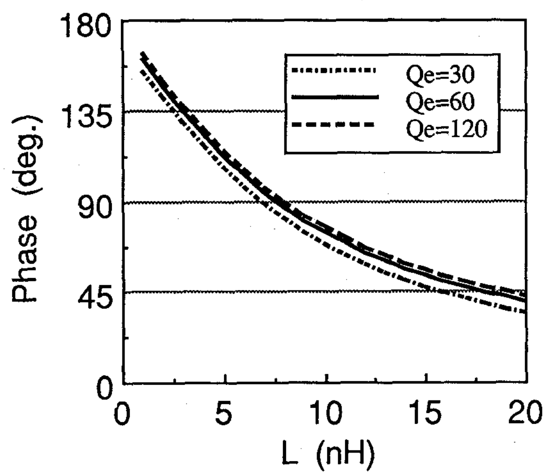


Fig.6 Relation between Inductance of Loop Prove and external Q

CONSTRUCTION OF THE DUPLEXER

A basic construction of high power duplexer in 800 MHz band using this vintage ASODRs is shown in Fig.7. One ASODR and two single TM_{110} mode dielectric resonators are used to construct a 4–section TX filter. And three ASODRs are used in 6–section RX filter construction. Coupling between ASODRs is controlled by using conductive slitted silver plated ceramic fins shown in Fig.4. This fin enables selective coupling of only one directional pair of ASODRs arrayed in series, and adjusts it by spacing of each fin. With these improved techniques, duplexer comprised of ASODRs was realized. External coupling loop proves at input and output ports are adjusted to couple only with one directional resonator mode. Outer electrodes of ASODRs are grounded, and resonators are grounded by soldering through meshed metal foils. The filter is mounted in a metal housing to assure the position of the resonators. This construction assures high stability against mechanical shock and high reliability against ambient temperature and humidity.

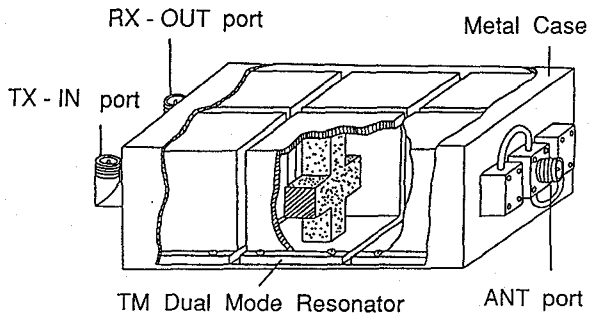


Fig.7 Basic Construction of the 800 MHz Band High Power Duplexer Using the Vintage ASODRs

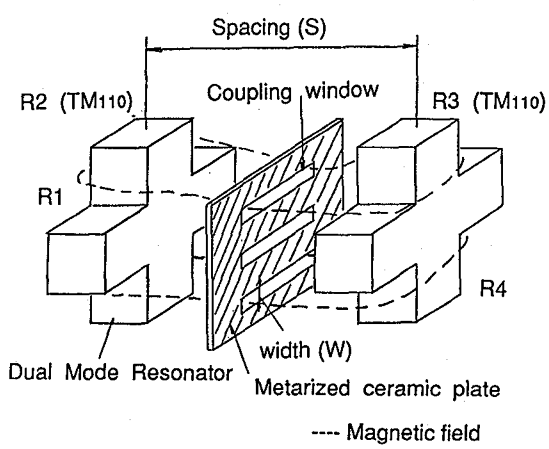


Fig.8 Magnetic Coupling between Dual Mode Resonators

PERFORMANCE OF THE DUPLEXER

By using ASODRs, a prototype duplexer in 800 MHz band was realized. Performance of the duplexer is shown in Table 1. Attenuation and return loss characteristic curves are shown in Fig.9. The experimental curve obtained shows good agreement with the calculated curve. Operating temperature range is -10°C to +60°C, and humidity range is 20% to 80%. Stability of frequency is about 1ppm/°C, and deviation of center frequency is about 30 KHz. Physical size is 152x83x180mm. It is about 60% of duplexer using TM_{110} single mode dielectric resonators only, and about 20% of conventional air cavity type duplexer. Significant size reduction can be realized. Weight of about 4.0kg assures easy handling of this duplexer, and it can easily be hand carried and set up at highly located equipment sites.

When input power is 70W, experimental temperature rise in the resonators is less than 15°C, which coinsides well with the calculated value. Measured value of third order intermodulation is less than -130 dBm at RX band. Mechanical shock of 50G maximum does not exert any adverse affects on filter characteristics. These shows successfully good practical performances and high reliability. External view of this filter is shown in Fig.10.

Table 1 Performance of the Duplexer

	TX	RX
Center Frequency	820 MHz	940 MHz
Passband Width	20 MHz	40 MHz
Insertion Loss	0.35 dB	0.47 dB
VSWR	1.10	1.17
Attenuation	92 dB at RX band	89 dB at TX band
Max.Input Power	500 W	
IMD	-130 dBm	
Physical Size	152x83x180 mm	
Weight	4.0 kg	

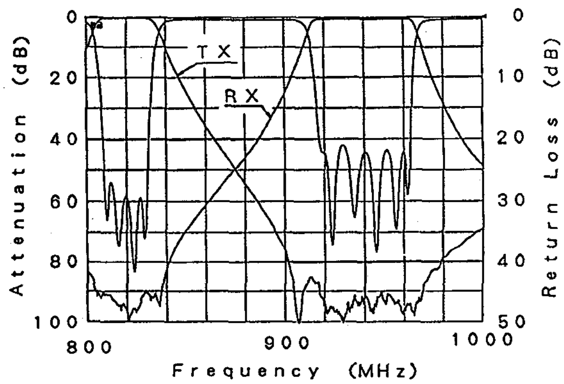


Fig.9 Attenuation and Return Loss Characteristic Curves of the Duplexer

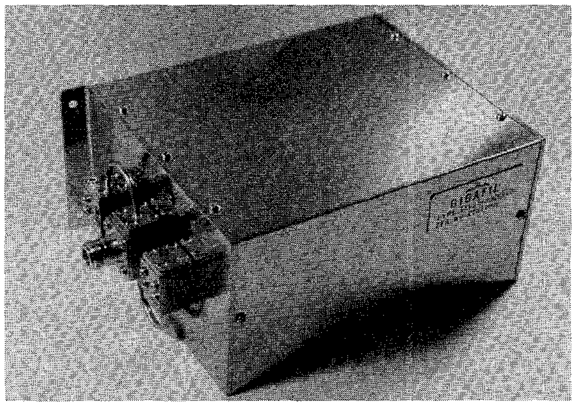


Fig.10 External View of the Duplexer

CONCLUSION

A small size, high power duplexer in 800-900 MHz band was developed using whole monoblock type TM_{110} dual mode dielectric resonators. TM_{110} dual mode dielectric resonator is small in size and has high unloaded Q and good high power characteristics. A new duplexing technique for dielectric bandpass filter was developed using TM_{110} dual mode resonators, and a duplexer was design and manufactured. Insertion loss is less than 0.35 dB at TX band and 0.47 dB at RX band, and the volume is about 2400 cc. This duplexer is very useful for cellular base stations.

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