B-2

Tchebyscheff Time-delay Dielectric Band-pass Filter Using Q Control Method of Normal Modes

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ABSTRACT

We have developed a Tchebyscheff time-delay three-pole band-pass filter in the 900MHz band by using the Q control method of normal modes. The group delay ripple of the filter is 50nsec within the 300kHz bandwidth.

The size of the equipment is W482.0 X D300.0 X H132.6 mm, and it can be put into a 19" standard rack. This filter is expected to be applicable for channel filters used in digital cellular base stations.

INTRODUCTION

Analog 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 reported transmitter multi-plexers which are important parts for them. These multiplexers have become smaller and less expensive by using dielectric resonators.[1)-3)]

Recently, as the development of speech security and ISDN services is progressing, digital cellular systems using narrow-band TDMA system are proposed. In this system, filters with small group delay ripple within the pass-band are necessary.

The conventional resonator type filters with Tchebyscheff time-delay characteristics have not been reported before. We developed a dielectric band-pass filter having these characteristics by using new circuit technology. In this paper, we describe the principles of this technology and compare with that of conventional filters. Also, we describe the performance and construction of the new filter.

PRINCIPLE

A conventional three-pole filter, in which dielectric resonators are arranged in cascade, is shown in Fig.1. It has three normal modes and its electric field distributions are shown in Fig.2. Not all loaded Q of normal modes can be controlled independently because these values are determined only by the external Q of the end resonators which couple directly to the load. Stored energy (Ws^i) in each normal mode A, B and C are in the ratio 4:2:4. Therefore, loaded Q of modes A and C are bigger than that of mode B according to the difinition of loaded Q (Q_L) as follows:

$$Q_L = \frac{W_S^i}{Pin} \cdot \omega \quad (i = A, B, C)$$

where Pin expresses input power.

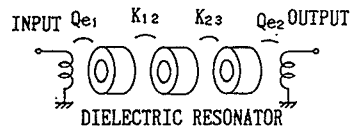

Fig.1 Construction of a conventional three-pole filter

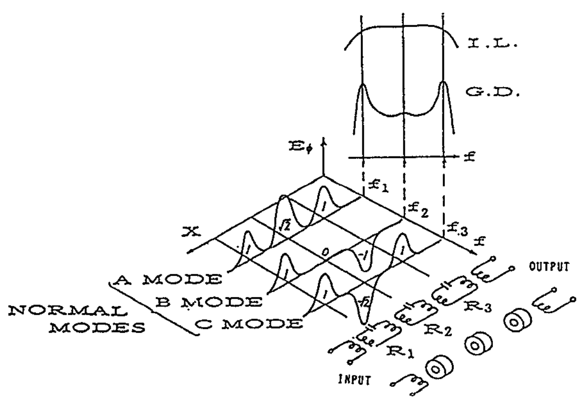

Fig.2 Electrical field distributions of a conventional three-pole filter

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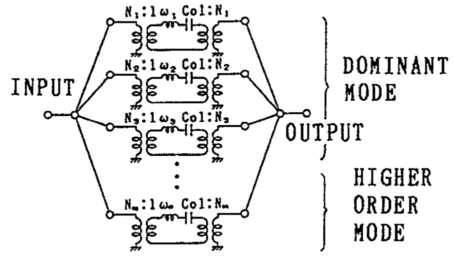


Fig.3 Equivalent circuit of a conventional three-pole filter

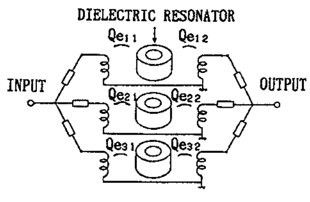


Fig.4 Construction of a three-pole PCF

On the other hand, the group delay (G.D.) of the one-pole filter at resonant frequency(ω_o) is expressed as follows:

$$\text{G.D.} = -\frac{d\theta}{d\omega} = \frac{2}{\omega_o} \cdot Q_L$$

From this relation, the group delay characteristics of the three-pole filter are closely proportional to the loaded Q of normal mode.

As a result, the group delay ripple of conventional filters is bigger at the edge of the pass-band shown in Fig.2.

In order to obtain filters with small group delay ripple within the pass-band, it is necessary to find a kind of circuit by which we can control the loaded Q of the normal mode independently. An equivalent circuit of the conventional three-pole filter shown in Fig.1 is expressed by the normal mode expansion[4] as shown in Fig.3. In this equivalent circuit, we propose that we replace the circuits that express the dominant three normal modes with three $TE_{01\delta}$ mode dielectric resonators and remove others that express higher order normal modes. This circuit is shown in Fig.4. The electric field distributions of this circuit as shown in Fig.5 leads us to understand that its distributions of one resonator is composed of almost one frequency components. Therefore, in the circuit of Fig.4, the external Q of each resonator or each mode can be controlled independently. We call this process the Q control method of normal modes, and we call this filter a Parallel Connected Filter (PCF). We can expect to obtain Tchebyscheff time-delay characteristics in this PCF.

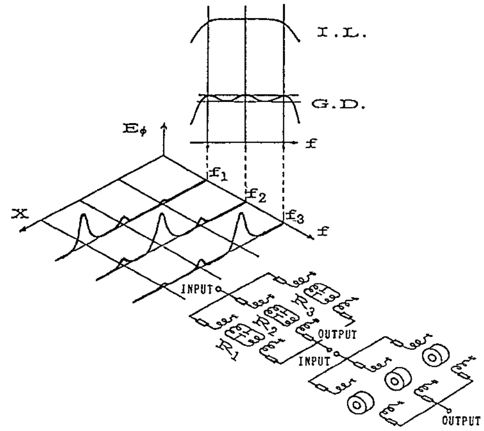


Fig.5 Electrical field distribution of a three-pole PCF

CONSTRUCTION

A simplified construction of a PCF is shown in Fig.6. A PCF consists of three resonators, junction boxes, input and output port transmission lines, a mechanical frame and a case. The resonator has the same construction as the filter previously reported by us,[1] and it is fixed to the aluminum frame. The junction box consists of a coupling loop, transmission line and Tee junction. The input and output port transmission lines are 50 ohms coaxial semi-rigid cable. The connectors of input and output terminals are N-females. The case is made of aluminum plate.

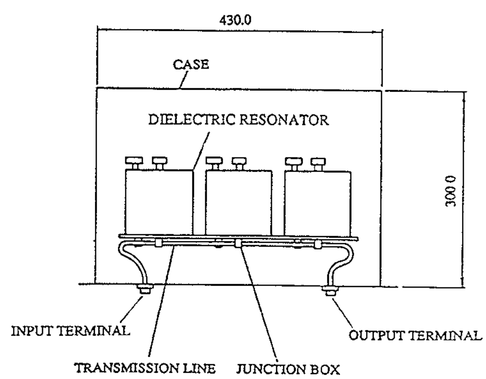


Fig.6 Construction and demensions of a three-pole PCF

DESIGN

The equivalent circuit of a PCF is shown in Fig.7. R_i(i=1,2,3) expresses a resonator, m_{ij}(i,j=1,2,3) expresses inductive coupling between the coupling loop and the resonator,

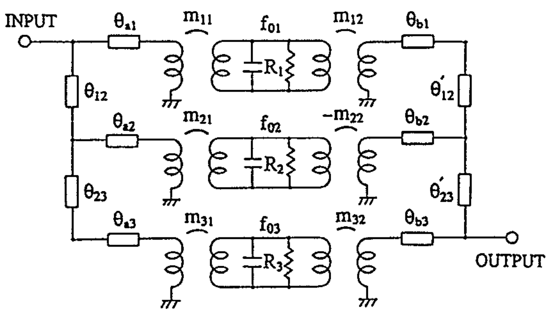


Fig.7 Equivalent circuit of a three-pole PCF

and θ_{ai}, θ_{bi} (i=1,2,3) and $\theta_{i,i+1}$, $\theta'_{i,i+1}$ (i=1,2) express the electrical length of the transmission line. $\theta_{i,i+1}$ is set to $\lambda/2$, and θ_{ai} and θ_{bi} are set to $\lambda/4$. As shown in the figure, a minus sign is added to m_{22}, because the phase difference between one resonator and another that has the next resonant frequency must be 180 degrees.[4]

The flow-chart for determining design parameters is shown in Fig.8. Qo expresses the unloaded Q of R_i. Q_{Li} is given by setting m_{ij} (j=1,2) independently. First, we set initial values of Qo, fo_i and Q_{Li} so that the transmission curve consists of that for each resonators. That is to say, each fo_i is tuned in the pass band at a regular frequency interval, and each Q_{Li} is equal to the others. Next, we optimize their values by simulation using microwave CAD to get the required characteristics. Thus, we realized Tchebyscheff time-delay characteristics as shown in Fig.9(a). Furthermore, in this circuit, we can design filters with maximally flat time-delay characteristics as shown in Fig.9(b).

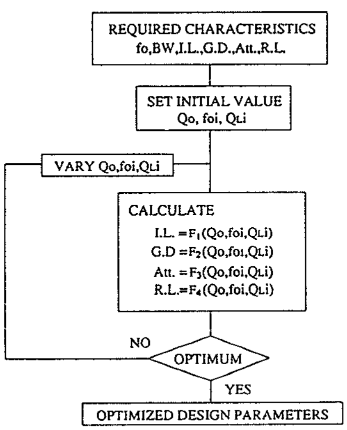
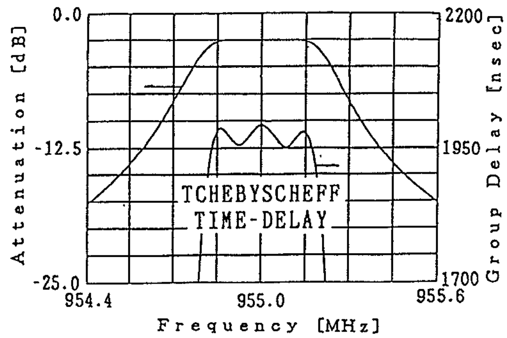
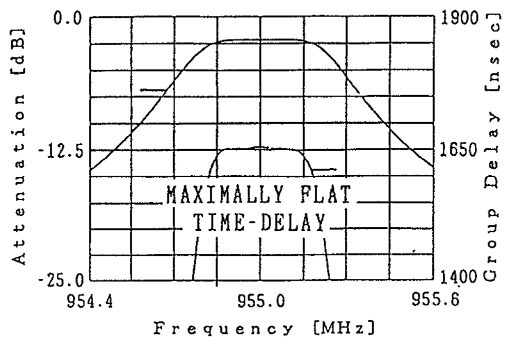


Fig.8 Flow-chart of simulation of a PCF



(a) Tchebyscheff time-delay characteristics



(b) Maximally flat time-delay characteristics

Fig.9 Transmission characteristics of a three-pole PCF (Calculated)

Table 1 Performance of the filter

Frequency	935～960MHz
Bandwidth	300KHz
G.D. Ripple at BW	50nsec
I.L. at BW	2.6dB
R.L at BW	13dB
Attenuation at fo±600kHz	17.5dB

PERFORMANCE

We have trial manufactured PCF for 900MHz band. The filter uses high Q $TE_{01\delta}$ mode dielectric resonators with K of 38, and the unloaded Q is 22000.

The performance of the filter is shown in Table 1. In the 300kHz bandwidth, the group delay ripple is 50nsec. Also, the insertion loss is 2.6dB and the return loss is over 13dB. The attenuation is 17.5dB at fo±600kHz. The transmission characteristics of the PCF are shown in Fig.10. Tchebyscheff time-delay characteristics that have equal ripple of the group delay within its bandwidth.

An external view of the PCF is shown in Fig.11. The size of the PCF is W482.0 X D300.0 X H132.6 mm.

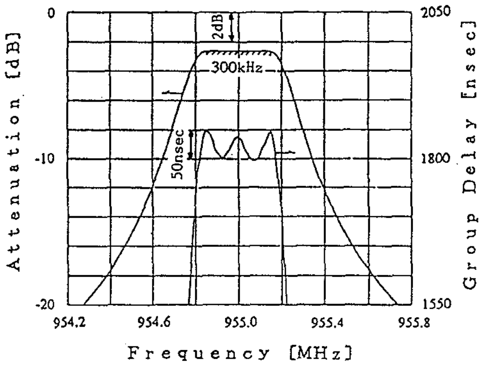


Fig.10 Transmission characteristics of trial manufactured PCF (Measured)

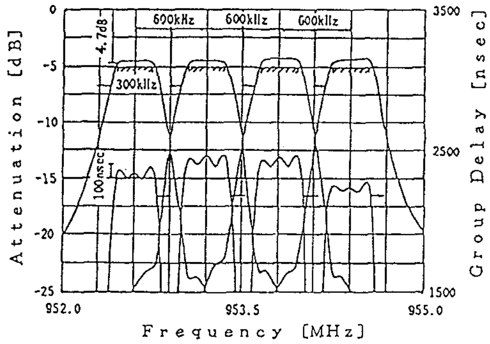


Fig.12 Transmission characteristics of trial manufactured transmitter multiplexer (Measured)

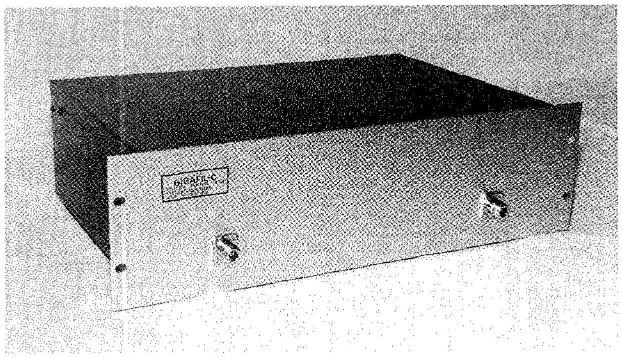


Fig.11 External view of a PCF

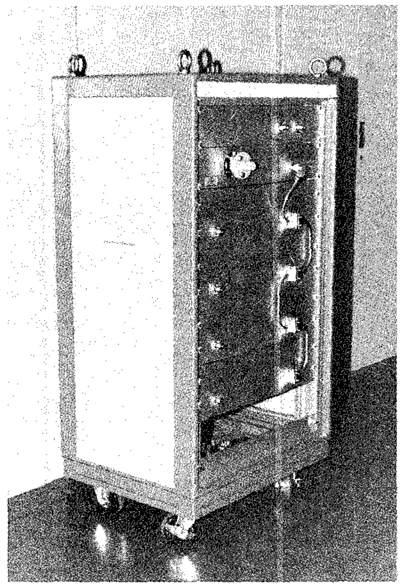


Fig.13 External view of a transmitter multiplexer

For application, by combining this PCF in the conventional method[2] and using dielectric TM_{110} mode high-power antenna filter[3] and isolators, we realized the four-channel transmitter multiplexer. Its transmission characteristics are shown in Fig.12 and its external view is shown in Fig.13. This multiplexer is useful for 900MHz band digital cellular base stations.

CONCLUSION

A 900MHz band Tchebyscheff time-delay three-pole band-pass filter was developed. The group delay ripple is 50nsec within a 300kHz bandwidth. The insertion loss is 2.6dB within its bandwidth. The size of the equipment is W482.0 X D300.0 X H132.6 mm.

Tchebyscheff time-delay characteristics are obtained by using Q control method of normal modes, which we proposed.

Low insertion loss and small size are obtained by using high Q (Qo=22000) and high K (K=38) dielectric resonators.

This band-pass filter is applicable for channel filters used in 900MHz band digital cellular base stations.

REFERENCES

1) T.Nishikawa, et al.,"800 MHz Band Channel Dropping Filter Using Low Loss Dielectric Resonator", IECE Technical Report, MW86-8, pp.55-61, 1986.
2) K.Wakino, et al., "5 Channel Dielectric Transmitter Multiplexer for 800 MHz Band Cellular System Base Station", Denshi Tokyo, IEEE Tokyo Section, No.25, 1985.
3) T. Nishikawa, et al., "800MHz High-power Bandpass Filter Using TM_{110} Mode Dielectric Resonators for Cellular Base Stations", IEEE MTT-S Int. Microwave Symp. Dig., pp.519-522, 1988.
4) Hsu Jui-Pang, et al., "Synthesis of Microwave Circuits by Normal Mode Expansion", IECE Technical Report, MW82-54, pp.9-19, 1982.