A BROADBAND DIELECTRIC DIPLEXER USING A SNAKED STRIP–LINE

Moriyasu Miyazaki, Hideki Asao, and Osami Ishida

Mitsubishi Electric Corporation,
5–1–1 Ofuna, Kamakura–city, Kanagawa–prefecture, 247, JAPAN

ABSTRACT

A diplexer comprised of a snaked strip–line low–pass filter and a dielectric band–pass filter was developed. Sharper cutoff characteristics of the low–pass filter permit reduction of the element number. In addition, the filters are miniaturized by use of high–permittivity dielectric. A 1GHz–band diplexer with dimensions 12mm×50mm×50mm was fabricated.

INTRODUCTION

A broadband diplexer with a narrow guardband is desirable for an effective use of the communication band. A broadband diplexer comprised of a semi–lumped element low–pass filter and a double–stub type band–pass filter was reported(1). However the size is too large for very small aperture terminal(VSAT) and satellite applications.

In this paper , a broadband diplexer comprised of a snaked strip–line low–pass filter and a dielectric interdigital band–pass filter is presented. The low–pass filter is constructed of alternate sections of high–impedance and low–impedance strip–line. The low–impedance sections of the snaked strip–line are located side by side and loaded with dielectric blocks. The bridging coupling between the low–impedance sections gives an attenuation pole just outside the passband, and the cutoff characteristics become sharper. The dimensions of the low–impedance sections are reduced by the effect of high–permittivity of the dielectric blocks.

In order to reduce the size of the band–pass filter, the inner conductors are sandwiched between two dielectric plates. A broad passband is obtained by adopting the impedance–step coupling(2) to the input and output lines at the open end of the first and last resonators.

A compact broadband diplexer was obtained by reducing the number and size of sections and resonators. The design theory and experimental results of the diplexer are described.

CONFIGURATION

Figure 1 shows a schematic configuration of the diplexer. A low–pass filter and a band–pass filter are connected in series. The low–pass filter consists of low– and high–impedance sections of symmetrical suspended stripline with inner conductors on both sides of a thin dielectric substrate. The low–impedance sections of the snaked suspended stripline are located side by side. Dielectric blocks are inserted

R

between the inner conductors and the outer conductors of the low–impedance sections as shown in Figure 2. By the effect of high permittivity of the dielectric blocks, the dimensions of the low–impedance sections are reduced and tight bridging coupling between neighbouring low–impedance sections is obtained.

The band–pass filter is an interdigital filter constructed of parallel 1/4 wavelength resonators. In order to reduce the length of the resonators, the inner conductors are sandwiched between two dielectric plates. The input and output lines are connected directly to the open ends of the first and the n–th resonators. The coupling is adjusted by the impedance of the first and the n–th resonators. The impedance–step coupling is suitable to get tight coupling required for a broad pass–bandwidth filter[2].

Figure 3 shows an equivalent circuit of the diplexer. The high– and low–impedance sections of the low–pass filter correspond to the series inductance L_i and shunt capacitance C_i, respectively, and the bridging coupling, to the capacitance C_{pi}. The attenuation pole is obtained at the parallel resonant frequency of L_i and C_{pi}. The resonators of the bandpass filter correspond to the stubs with admittance Y_i. Since the input impedance of the series connected filters becomes very low at their respective rejection bands, the good VSWR characteristics of the filters are maintained in the diplexer.

DESIGN THEORY

(1) SNAKED STRIP–LINE LOW–PASS FILTER

The shunt capacitances C_i ($i=2,4,\cdots,m-1$: m is odd number) and the series inductances L_1 and

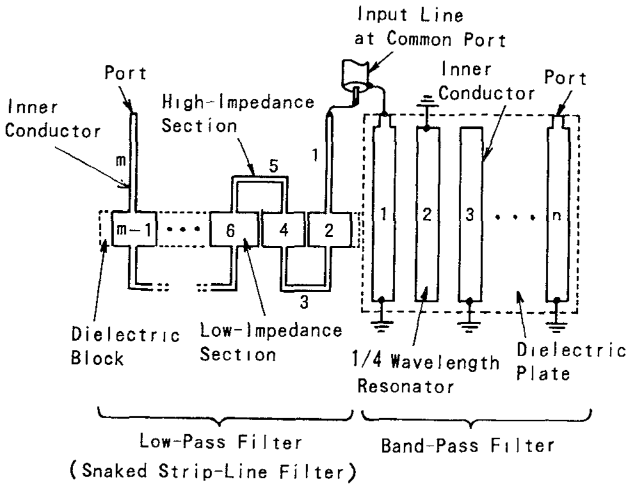

Fig.1 Schematic configuration of diplexer.

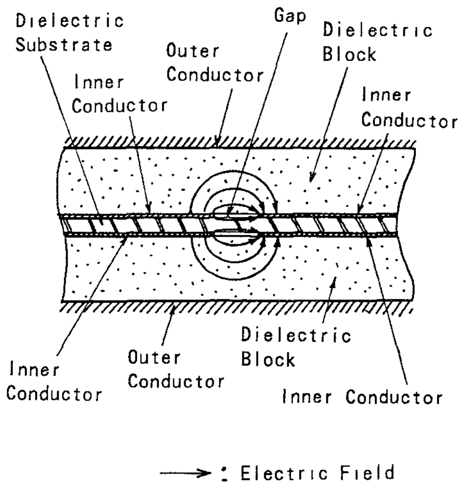

Fig.2 Cross–sectional view of low–impedance sections.

L_m are determined from the element values of the low–pass prototype filter[3]. L_i and C_{pi} ($i=3,5,\cdots,m-2$) of the parallel resonant circuits are determined from the conditions that the parallel resonant circuits resonate at the angular frequency ω_p just outside the passband, and that the reactances of the parallel resonant circuits coincide with the series reactances of the prototype filter at the angular frequency ω_0 in the passband. Thus, the parameters of the equivalent circuit are given by the following equations.

$$C_i = (g_0 / Z_A)(\omega_1' / \omega_c)\, g_i \qquad (i=2,4,\cdots,m-1) \quad (1)$$

$$L_i = (Z_A / g_0)(\omega_1' / \omega_c)\, g_i \qquad (i=1,m) \quad (2)$$

$$L_i = (g_i / \omega_c)[1 - (\omega_0 / \omega_p)^2] \qquad (i=3,5,\cdots,m-2) \quad (3)$$

$$C_{pi} = \frac{\omega_c}{g_i} \cdot \frac{1}{\omega_p^2 [1 - (\omega_0 / \omega_p)^2]} \qquad (i=3,5,\cdots,m-2) \quad (4)$$

where g_i (i=0,1,·····,m) and ω_1' are the element values and the cutoff frequency of the low-pass prototype filter[3], Z_A is the characteristic impedance of the input and output lines, and ω_c is the cutoff angular frequency.

Figure 4 shows the calculated attenuation characteristics of the snaked strip-line low-pass filter in comparison with a Tchebyscheff-type conventional filter. The snaked strip-line filter has an attenuation pole at $1.5\omega_c$ and sharper cutoff characteristics. The value of ω_0 was chosen as $0.8\omega_c$.

(2) DIELECTRIC BAND-PASS FILTER

The even-mode admittances Y_1 and Y_n of the first and the n-th cavities are determined from the definition of the external Q of a resonator coupled by impedance step, as follows

$$Y_1 / Y_A = Y_n / Y_A = (4/\pi)\, Q_e \quad (5)$$

$$Q_e = g_0\, g_1\, \omega_1' / w \qquad (\omega_1' = 1) \quad (6)$$

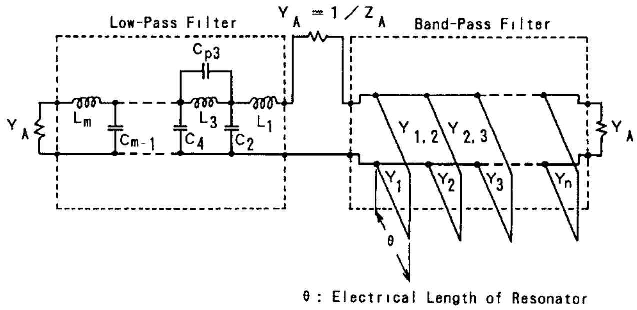

Fig.3 Equivalent circuit of diplexer.

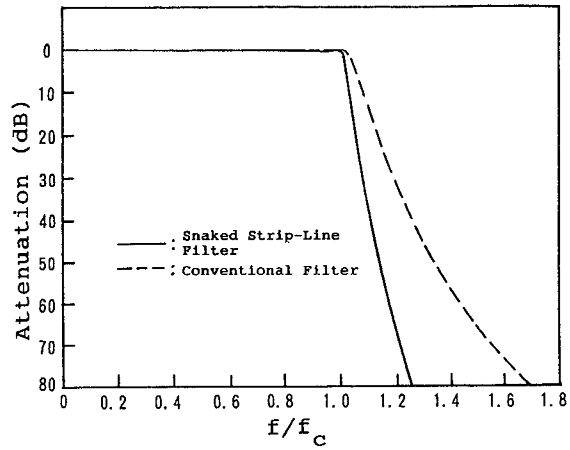

Fig.4 Calculated attenuation characteristics of snaked strip-line low-pass filter in comparison with conventional filter, for m=13.

where Y_A is the characteristic admittance of the input and output lines, Qe is the external Q of the first and the n-th cavities, and w is the fractional pass-bandwidth.

From the equation for the mutual coupling coefficient $k_{i,i+1}$ (i=1,2,·····,n-1)[4], the mutual admittances $Y_{i,i+1}$ (i=1,2,·····,n-1) are given by

$$Y_{i,i+1} = \frac{Y_i + Y_{i+1} + \sqrt{(Y_i + Y_{i+1})^2 + 4 Y_i Y_{i+1} \tan^2 [(\pi/2)(1 - k_{i,i+1}/2)]}}{2\tan^2 [(\pi/2)(1 - k_{i,i+1}/2)]} \quad (7)$$

$$k_{i,i+1} = w / \sqrt{g_i\, g_{i+1}} \qquad (\omega_1' = 1) \quad (8)$$

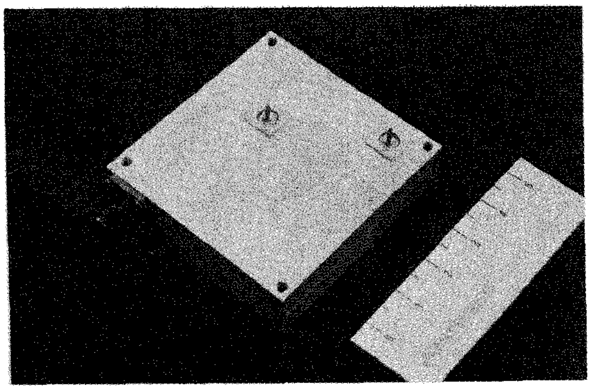

Fig.5 Photograph of fabricated diplexer.

EXPERIMENTAL RESULTS

A diplexer was fabricated in the 1GHz band with a thirteen–element low–pass filter and a seven–resonator band–pass filter. Dielectric blocks and plates with dielectric constant 36 were used. Figure 5 shows the photograph of the diplexer. The dimensions are 12mm×50mm×50mm.

Figure 6 shows the attenuation characteristics. The insertion loss is less than 1dB in the passbands below $0.87f_{g0}$ and between $1.13f_{g0}\sim1.57f_{g0}$. The isolation is more than 50dB in the same frequency bands. Figure 7 shows the reflection characteristics. The VSWR is less than 1.6 in the passbands.

CONCLUSION

A compact broadband diplexer comprised of a snaked strip–line low–pass filter and a broadband dielectric band–pass filter has been presented. The sharper cutoff characteristics obtained by the snaked strip–line, permitted reduction of the sections of the low–pass filter. This diplexer is useful for the satellite communication.

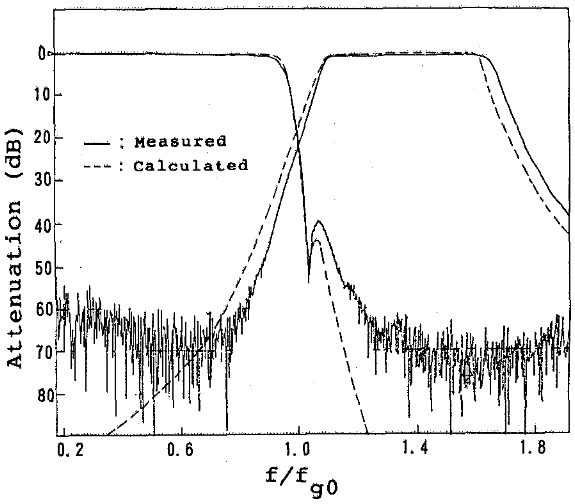

Fig.6 Attenuation characteristics of diplexer for m=13, n=7.

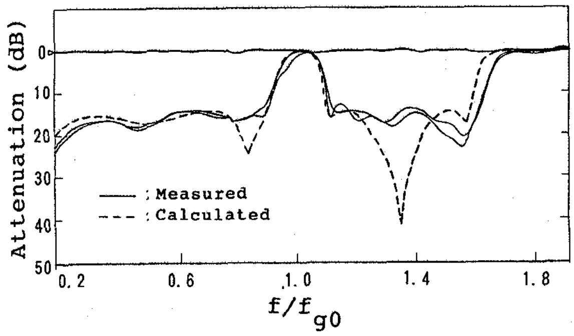

Fig.7 Reflection characteristics of diplexer for m=13, n=7.

REFERENCES

(1) G.L.Matthaei, L.Young, and E.M.T.Jones, " Microwave Filters, Impedance–Matching Networks, and Coupling Structures," McGraw–Hill, 1964., Sec.16.5.

(2) G.L.Matthaei, L.Young, and E.M.T.Jones, op. cit. (1), Sec.10.7.

(3) G.L.Matthaei, L.Young, and E.M.T.Jones, op. cit. (1), Sec.4.4–4.6.

(4) M.Dishal, " Alignment and Adjustment of Synchronously Tuned Multiple–resonant–circuit Filters," Proc. IRE, pp.1448–1450, Nov.1951.