Ring-Filter Switch

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Abstract

A ring-filter switch is suggested. It consists of a ring and two short stubs which are connected at 90° and 270° point of the ring. The ring-filter is a wideband filter and can be a band-stop filter when a certain condition is satisfied. The fact is used as a switch. To verify it, a microstrip ring-filter switch is fabricated on a substrate (ε_r = 4.8, H = 0.57 mm) and measured at a center frequency of 3 GHz. The measured results are in good agreement with the predictions.

Key words : Ring-filter switch, Ring filters, wideband filter and sharp band-stop filter.

I. Introduction.

A switch is a device for changing the flow of a circuit. The prototypical model is a mechanical device which can be disconnected from one course and connected to another. The term "switch" typically refers to electrical power or electronic telecommunication circuits. In modern microwave communication system, any switch with very sharp band-stop filter is needed to reduce harmonics produced from high power system. For this purpose, the ring-filter switch is suggested.

The ring-filter was for the first time suggested as a wideband 180° transmission line [1]-[4]. It consists of a ring and two short stubs which are connected at 90° and 270° points of the ring to reject DC and even-multiples of a design center frequency. Feeding lines are directly coupled to a ring to alleviate high insertion loss caused by gaps in conventional ring-based circuits. In the ring filter, the power excited at input is divided just like ring hybrids or three-port power dividers [5]-[6] and the divided powers are combined at the output like a three-port power combiner. The two combined powers are in almost same frequency responses, which is the main reason why the ring filter has such wideband responses. Therefore, it may be seen in other sense that two filters, "up-" and "down-" filters are connected in parallel. If the two combined powers at the output are the same in magnitude and out of phase, the excited power can not be delivered to the output. This may be done by making the two short stubs differ in length and can be used for an off-state of the switch. The main reason of no power transmission is that the voltages where two short stubs are connected are the same in magnitude and out of phase. Therefore, if the voltages are made same, or, the two positions are connected with each other, a power transmission may be accomplished. This state can be used for the on-state of the switch.

To verify the ring-filter switch, a microstrip ring-filter switch was designed at a center frequency of 3 GHz and fabricated on a substrate (ε_r = 4.8,

$H = 0.57$ mm). The measured results are in good agreement with predictions.

II. Analyses

The ring filters are depicted in Fig. 1 where its up-filter in Fig. 1(b). It is terminated in Z_1 and Z_2, and consists of a ring and two short stubs. The two short-stubs are located at 90° and 270° points of the ring and the point where each short stub is connected may be considered as a hypothetical port whose termination impedance is Z_h. The Z_h is needed to design the ring filter and may arbitrarily be chosen when $Z_1 = Z_2$, and $Z_h = (Z_1 + Z_2)/2$ or $\sqrt{Z_1 Z_2}$ in the case of $Z_1 \neq Z_2$.

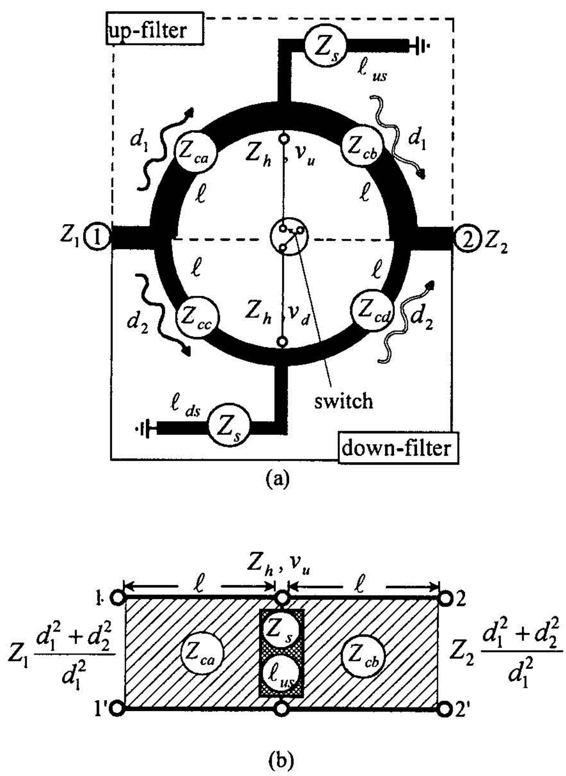

Fig. 1. Ring filter.
(a) Ring filter (b) Up-filter

The length of four transmission-line sections forming a ring is equally ℓ and their characteristic impedances are Z_{ca}, Z_{cb}, Z_{cc} and Z_{cd}. The length of the short stub in the up-filter is ℓ_{us} and that of the down filter ℓ_{ds}.

The *ABCD* parameters of the up-filter in Fig. 1(b) are

$$A_u = \cosh^2 \gamma\ell + \frac{Z_{ca}}{2Z_s} \sinh 2\gamma\ell \coth \gamma\ell_{us} + \frac{Z_{ca}}{Z_{cb}} \sinh^2 \gamma\ell \quad (1)$$

$$B_u = \frac{Z_{ca} + Z_{cb}}{2} \sinh 2\gamma\ell + \frac{Z_{ca} Z_{cb}}{Z_s} \sinh^2 \gamma\ell \coth \gamma\ell_{us}$$

$$C_u = \frac{\sinh 2\gamma\ell}{2Z_{ca}} + \frac{1}{Z_s} \cosh^2 \gamma\ell \coth \gamma\ell_{us} + \frac{\sinh 2\gamma\ell}{2Z_{cb}}$$

$$D_u = \frac{Z_{cb} \sinh^2 \gamma\ell}{Z_{ca}} + \frac{Z_{cb}}{2Z_s} \coth \gamma\ell_{us} \sinh 2\gamma\ell + \cosh^2 \gamma\ell \ ,$$

where $\gamma = \alpha + j\beta$ (α and β: attenuation and phase constants),

$$Z_{ca} = \sqrt{Z_1 Z_h \frac{d_1^2 + d_2^2}{d_1^2}}, \quad Z_{cb} = \sqrt{Z_2 Z_h \frac{d_1^2 + d_2^2}{d_1^2}}.$$

In the same way, those of the down-filter are

$$(2)$$

$$A_d = \cosh^2 \gamma\ell + \frac{Z_{cc}}{2Z_s} \sinh 2\gamma\ell \coth \gamma\ell_{ds} + \frac{Z_{cc}}{Z_{cd}} \sinh^2 \gamma\ell$$

$$B_d = \frac{Z_{cc} + Z_{cd}}{2} \sinh 2\gamma\ell + \frac{Z_{cc} Z_{cd}}{Z_s} \sinh^2 \gamma\ell \coth \gamma\ell_{ds}$$

$$C_d = \frac{\sinh 2\gamma\ell}{2Z_{cc}} + \frac{1}{Z_s} \cosh^2 \gamma\ell \coth \gamma\ell_{ds} + \frac{\sinh 2\gamma\ell}{2Z_{cd}}$$

$$D_d = \frac{Z_{cd} \sinh^2 \gamma\ell}{Z_{cc}} + \frac{Z_{cd}}{2Z_s} \coth \gamma\ell_{ds} \sinh 2\gamma\ell + \cosh^2 \gamma\ell$$

where

$$Z_{cc} = \sqrt{Z_1 Z_h \frac{d_1^2 + d_2^2}{d_2^2}}, \quad Z_{cd} = \sqrt{Z_2 Z_h \frac{d_1^2 + d_2^2}{d_2^2}}$$

Lossless ($\alpha = 0$) and no discontinuity effect are assumed and if ℓ, ℓ_{us} and ℓ_{ds} are set as written in (3),

$$\beta_o \ell = \pi/2, \quad (3)$$

$$\beta_o \ell_{us} = \pi/2 + \mu$$

$$\beta_o \ell_{ds} = \pi/2 + \nu,$$

the Y-parameters are derived as

$$Y = -jZ_s \frac{\sin(\mu+\nu)}{\sin\mu \sin\nu} \begin{bmatrix} \frac{1}{Z_{ca}^2} & \frac{1}{Z_{ca}Z_{cb}} \\ \frac{1}{Z_{ca}Z_{cb}} & \frac{1}{Z_{cb}^2} \end{bmatrix}, \quad (4)$$

which are derived at a center frequency and the case of an equal power division, or, $d_1 = d_2$.

$\mu \neq 0$, $\nu \neq 0$ and $\mu + \nu = 0$ in (4) result in

$$Y = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \quad (5)$$

(5) implies that matching and power transfer can not occur with the condition $\mu + \nu = 0$. Therefore, the condition $\mu + \nu = 0$ is a necessary and sufficient condition for the zero vector of Y-parameters. The prime reason of no matching and no power transmission at the center frequency is that the voltages of v_u and v_d in Fig. 1 are same in magnitude but 180^o out of phase. If the different voltages, v_u and v_d are made same, or, the two points with v_u and v_d are connected with each other, it will operate a normal ring filter. This may be used for the switch. With on-state of the switch, it could have a few ohms between the two hypothetical ports.

Fig. 2 shows simulated scattering parameters of the ring-filter switch where those of the off-state are plotted in Fig. 2(a) and those of on-state in Fig. 2(b). For the simulations, all the characteristic impedances, Z_{ca}, Z_{cb}, Z_{cc} and Z_{cd} are equally 70. 71 Ω and $\mu = 30^o$. With on-state, 1 Ω resistance is used between the two hypothetical ports.

As shown in Fig. 2 (a), the insertion loss at a center frequency of 1 GHz is almost -200 dB and the return loss 0 dB, which are the band-stop characteristics. With on-state in Fig. 2(b), the insertion loss is 0 dB and the return loss -70 dB, which are the band-pass characteristics.

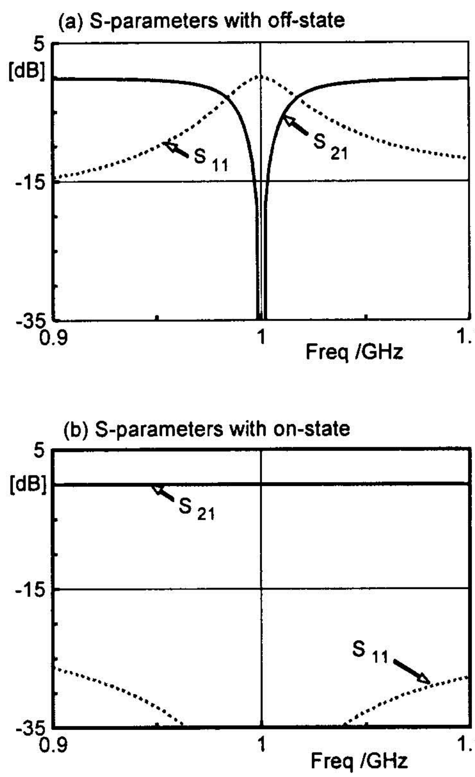

Fig. 2. Simulated scattering parameters of the ring filter switch. (a) Off-state (b) On-state.

III. Measurements

Based on the analyses, a ring-filter switch was designed at a center frequency of 3 GHz and fabricated on a substrate (ε_r = 4.8, H = 0.57 mm).

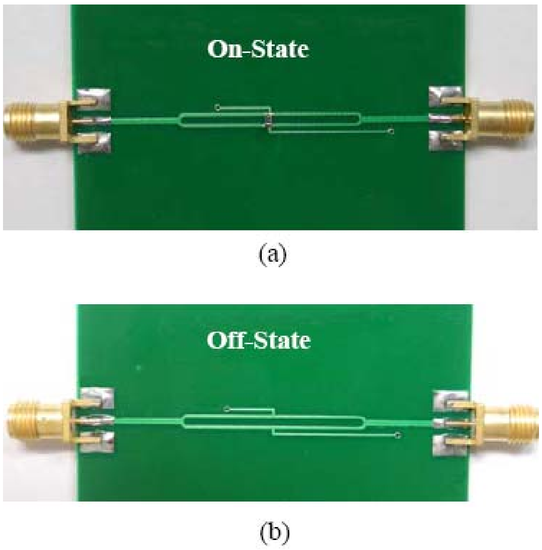

Fig. 3. Ring-filter switch (a). On-state (b)Off-state.

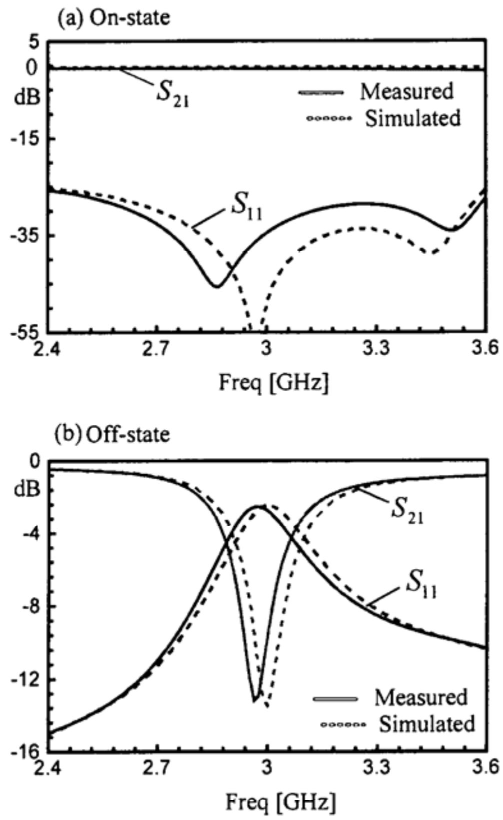

Fig. 4. Measured results are compared with predictions. (a) On-state (b)Off-state.

The two states of the ring-filter switches are shown in Fig. 3 where the on-state is in Fig. 3(a) whereas the off-state in Fig. 3(b) . In this case, $\beta_o \ell = 90^o$, $\beta_o \ell_{us} = 50^o$, $\beta_o \ell_{ds} = 130^o$, Z_{ca}, Z_{cb}, Z_{cc} and Z_{cd} are equally 70. 71 Ω, $Z_s = 85\Omega$ and the 1 Ω resistor is connected between two hypothetical ports. The measured results are compared with the predictions in Fig. 4 where the solid lines are measured data and the dotted ones simulated ones. The measured results appear to be in good agreement with the predictions.

IV. Conclusions.

The ring-filter switches were introduced and analyses. Depending on the states of the switch, a wideband filter or a band-stop filter can be produced. Therefore, it can be used for a various applications such as high power system to reduce harmonics.

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