Modeling of Antipodal/BCSSS Transition for Millimeter Wave Finline High Q Local Injected Mixer

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ABSTRACT

Millimeter-wave application in intelligent vehicle sensor and others has been in great demand recently for it's small size, high data rate and high resolution property. In this paper, we report our design and simulation of an antipodal finline to broadside coupled suspended substrate stripline (BCSSS) transition to be used in a millimeter-wave mixer. In our finline balanced mixer design, the LO power was coupled to the mixer diodes through this transition. The antipodal finline served as an impedance transformer between the WR-28 waveguide impedance of 480Ω and the BCSSS bandpass filter impedance of 50Ω. Both the fingaps, i.e., between the antipodal tapered finlines and the WR-28 waveguide as well as between antipodal tapered finlines and BCSSS bandpass filter were varied to achieve optimum impedance matching. Antipodal finline to BCSSS bandpass filter transition designed in this paper has a minimum insertion loss at 26GHz.

1 INTRODUCTION

The term "millimeter wave" is taken from the fact that the wavelength of radio signals between 30 GHz and 300 GHz ranges from 10 millimeters down to 1 millimeter. This action makes available three frequency bands: 47.6-47.8 GHz, 59-64 GHz, and 76-77 GHz, for unlicensed vehicle radar systems and general purpose unlicensed devices. Vehicle radar systems could be used for vehicle control applications, such as collision warning and avoidance, automatic cruise control, and lane guidance. The 46.7-46.9 and 76-77 GHz frequency allocation may spur the development of Intelligent Transportation Systems intended to improve highway safety. No other users will be permitted in these bands at this time, including amateur operation in the 76-77 GHz band.

In this paper, we report the design of an antipodal finline to broadside coupled suspended substrate stripline (BCSSS) transition to be used in a millimeter wave mixer. A finline W-band balanced mixer has been reported by Tahim for wide-band operation [1]. RF is fed through a cosine taper finline transition and LO power is coupled to the mixer diodes through a cosine antipodal taper finline transition via a suspended substrate stripline bandpass filter. The LO bandpass filter built on suspended substrate stripline is implemented to achieve good RF to LO isolation. The insertion loss of this filter was reported to be about 1.5dB over a 5GHz bandwidth. In order to obtain better RF to LO isolation, this paper presents a design of a broadside coupled suspended substrate stripline capacitive-coupled bandpass filter for a LO frequency of 26GHz. This filter was designed and simulated as an individual component and the insertion loss was 0.5dB at f_0 = 26GHz.

An exponential antipodal finline taper was designed to achieve high Q LO [2]. This taper will transform the waveguide impedance of 480Ω to match the suspended substrate stripline impedance of 50Ω. In this finline-to-suspended substrate stripline transition, the waveguide has to be modified to suit this transition. This paper presents the design of a waveguide transforming from a WR-28 to a 3.556mm x 1.778mm waveguide for antipodal finline to suspended substrate stripline transition respectively.

The waveguide-to-finline-to-suspended substrate stripline transition was simulated using HP HSFF software. The insertion loss was minimum at the operating frequency of 26GHz.

2. ANTIPODAL FINLINE TAPER

In our exponential antipodal finline taper, WR-28 waveguide and RT/Duroid 5880 substrate were used and their parameters are defined as follows and shown in Fig. 1.

a = Length of Cavity	= 7.112mm
b = Height of Cavity	= 3.556mm
s = Thickness of Substrate	= 0.254mm
ε_r = Dielectric of Substrate	= 2.22
d = Slot Width of Finline	= 0.8 - 3.556mm

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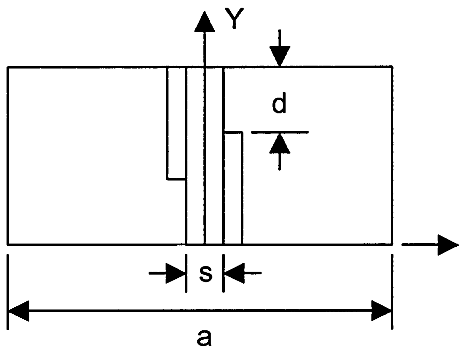
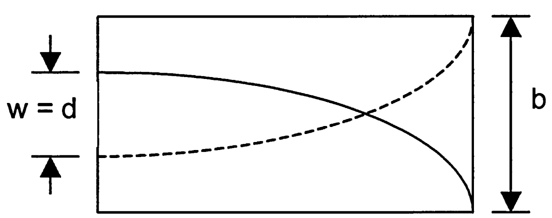


(a) Side View of Antipodal Finline Taper



(b) Front View of Antipodal Finline Taper

Fig. 1: Antipodal Finline Taper

3. SUSPENDED SUBSTRATE STRIPLINE

From Ref. [3] the structure of a shield suspended substrate stripline is shown in Fig. 2 with their parameters defined. In order for the waveguide-to-antipodal finline-to-suspended substrate stripline transition to take place, the following dimensions have to be defined.

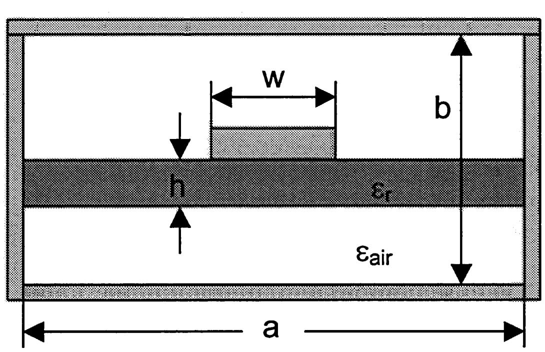


Fig. 2 Shielded Suspended Substrate Stripline

a = Length of Cavity	= 3.556mm
b = Height of Cavity	= 1.778mm
s = Thickness of Substrate	= 0.254mm
ε_r = Dielectric Constant of Substrate	= 2.22
d = w = Width of Suspended Stripline	= 2mm

4. BCSSS BANDPASS FILTER DESIGN

Ref. [4] provides a design procedure for broadside coupled suspended substrate stripline (BCSSS) capacitive coupled bandpass filter and is depicted in Fig. 3.

The BCSSS capacitive-coupled bandpass filter is required to operate at 26GHz. We selected a 5^{th}-order 0.1dB ripple Chebyscheff pass band with corner frequencies f_1 = 18GHz and f_2 = 35GHz.

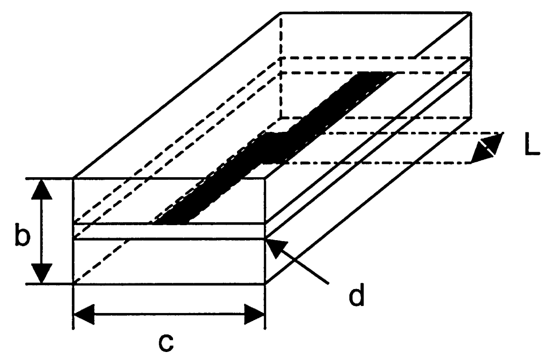


Fig. 3 Overlap Section Forming the Series Capacitance

With five reactive elements, the g values for this Chebychev lowpass prototype are [5]

$g_1 = 1.1468$, $g_2 = 1.3712$,

$g_3 = 1.9750$, $g_4 = 1.3712$, $g_5 = 1.1468$,

Using equations from Ref. [4], the resonator lengths and coupling capacitor values for a 50Ω resonators are listed in Table 1:

Resonator No.	Resonator Length	Coupling Capacitor Value C_i(pF)
1	103.14°	0.399
2	110.63°	0.205
3	114.04°	0.143
4	110.63°	0.143
5	103.14°	0.205
6		0.399

Table 1: Resonator and Coupling Capacitor

The even- and odd-mode impedances and effective dielectric constant can be determined as well and the calculated valued are shown in Table 2.

From Ref. [6], $K_1 = 1.295$, $K_2 = -0.2817$, $K_3 = 0.1367$, $K_4 = -0.0133$, $K_5 = -0.0267$, and with w = 2mm, h = 0.254mm, therefore

$C_f = 0.0235$pF

SSS	BCSSS	BCSSS
$Z_0 = 54\Omega$	$Z_{0e} = 93.21\Omega$	$Z_{0o} = 13.25\Omega$
$\varepsilon_{reff} = 1.18$	$\varepsilon_{reffe} = 1.1$	$\varepsilon_{reffo} = 1.98$
$C_0 = 67$pF/m	$C_{0e} = 37.5$pF/m	$C_{0o} = 353.75$pF/m

Table 2: Line Parameters for SSS BPF

The equivalent circuit of the overlap section of Fig. 3 is shown in Fig. 4 where C_{fend} is the capacitance off the ends of the overlap section.

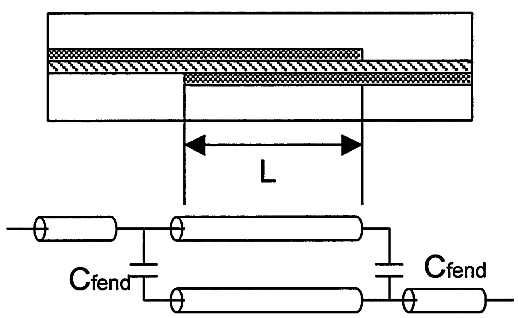


Fig. 4: Equivalent Circuit of the Overlap Section

Since $C_{fend} = 1.4C_f$, hence

$C_{fend} = 0.0329$pF.

The overlap of coupling capacitor and resonator length can then be obtained as shown in Table 3.

This BCSSS capacitive-coupled bandpass filter design was simulated using HP HFSS. Fig. 5, 6 and 7 show the structure, S21 and S11 of this BCSSS capacitive-coupled bandpass filter respectively.

Resonator No.	Resonator Length L_{ri} (mm)	Coupling Capacitor L_i (mm)
1	1.88	1.88
2	2.8	0.787
3	3.1	0.435
4	2.8	0.435
5	1.88	0.787
6		1.88

Table 3: Resonators and Overlap Lengths

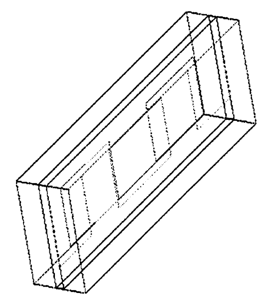


Fig. 5 Structure of Broadside Coupled Suspended Substrate Stripline Capacitive Coupled Bandpass Filter

Fig. 6 shows that at the operating frequency of 26GHz, S21 = 0.5dB. However, the peak point, i.e., at S21 = 0dB, is at 22.5GHz. Fine tuning can be done by adjusting the capacitive gaps of the filter to shift the peak point to 26GHz. By selecting different corner frequencies, the insertion loss can also be improved at operating frequency. However, this is may not be necessary as the insertion loss was already low at 26GHz.

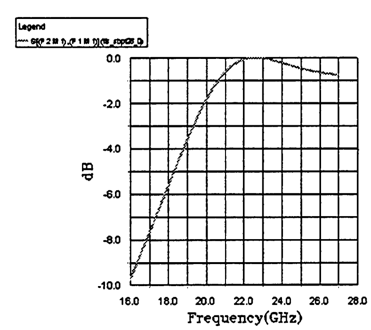


Fig. 6: S21 of Broadside Coupled Suspended Substrate Stripline Capacitive Coupled Bandpass Filter

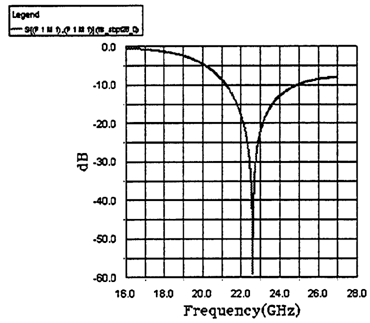


Fig. 7 S11 of Broadside Coupled Suspended Substrate Stripline Capacitive Coupled Bandpass Filter

Fig. 7 shows that at 22.5GHz, S11 = -60dB. This shows that the return loss is the minimum at the operating 22.5GHz. The reason of not improving the insertion and return losses at this juncture will be revealed in section VI.

5. FINLINE-TO-SUSPENDED STRIPLINE TRANSITION

Fig. 9 shows the structure of waveguide-to-antipodal finline-to-suspended substrate stripline transition. Notice the change from 7.112mm x 3.556mm waveguide for antipodal finline to 3.556mm x 1.778mm waveguide for BCSSS capacitive-coupled bandpass filter.

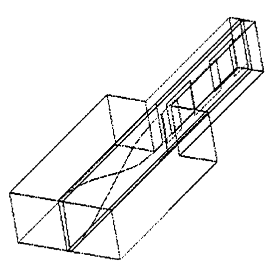


Fig. 9: Antipodal-To-Suspended Stripline Transition

Fig. 10 shows the insertion loss of the antipodal finline-to-BCSSS capacitive-coupled bandpass filter. Notice that the insertion loss is minimum at about 26GHz.

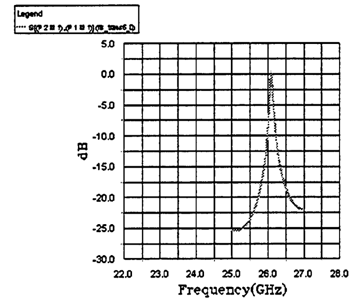


Fig. 10: S21 of Antipodal-To-Suspended Stripline Transition

6. CONCLUSION

In this paper, BCSSS capacitive-coupled bandpass filter has been designed and simulated. In order to achieve a 50Ω suspended substrate stripline with stripline width equals 2mm, the dimensions of the waveguide was determined to be 3.556mm x 1.778mm. As a result, the WR-28 waveguide for antipodal finline taper has to be modified to 3.556mm x 1.778mm for the transition to BCSSS capacitive-coupled bandpass filter. The insertion loss for this transition was minimum at 26GHz.

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