Miniature in Phase Hybrid Ring Equal Power Divider Using Tile EBG

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Abstract – In this paper, a miniature In Phase Hybrid Ring Equal Power Divider designed at frequency 4 GHz has been proposed. The power divider has been designed using a new type of EBG structure termed the ‘Tile EBG’ structure. A conventional Hybrid Ring Equal Power Divider has also been designed to operate at the same frequency for the sake of comparison. The proposed technique achieves 51.8% size reduction and approximately 8.5% increase in bandwidth.

Keywords – Electromagnetic Bandgap (EBG), Hybrid Ring Power Divider, Miniaturization, Tile EBG

I. INTRODUCTION

Owing to the simplicity in design, wide bandwidth in power-dividing distribution, and high isolation between different ports, the in-phase hybrid-ring equal power divider is the key component in the design of microwave devices such as power amplifiers, mixers, and antenna systems. The in-phase hybrid-ring equal power, also known as the Gysel power divider [1] usually assumes the shape of a ring impedance transformer. Modern wireless communication systems are continuously demanding smaller device size in order to meet circuit miniaturization and cost reduction. Thus, size reduction is becoming a major design consideration for practical application. Even in the low microwave frequency range, the physical size of the in-phase hybrid-ring equal power divider is still too large for some applications. Therefore, attempts are continually being made to reduce its size [4], [5].

Although there have been numerous reported papers on using electromagnetic-bandgap (EBG) cells for size reduction, to date, most of the methods of designing the EBG circuitry [5], [6] have been a trial-by-error parametric variation of the EBG unit cell structure through a full-wave electromagnetic simulation. This method does not provide any clear analytic review of the effect of geometrical dimensions of the EBG structure on the overall circuit’s performance.

The In Phase Hybrid Ring Equal Power Divider offers the advantages of high isolation and wide bandwidth and finds application where the incoming signal is to be split for providing to the distribution systems. Fig. 1 shows the layout of the conventional Hybrid Ring Power Divider designed at 4 GHz. Port 1 is the input port. Port 2 and 3 provide equal power signal. Ports 4 and 5 are termination ports for matching.

Electromagnetic Bandgap (EBG) structures are periodic structures with ability to control the propagation of electromagnetic waves. The EBG structures introduce a defect in the conventionally continuous microwave structure. Such defects increase the effective inductance and capacitance. The current now encounters more impedance than it would in absence of the defect and hence its velocity decreases. Hence, the structure is also termed as SWS (Slow Wave Structure).

\[
V_p = \frac{1}{\sqrt{LC}} \quad (1)
\]

\[
\lambda_E = \frac{V_p}{f} \quad (2)
\]

\[
\varepsilon = \left( \frac{\lambda}{\lambda_E} \right)^2 \quad (3)
\]

\[
Z_0 = \sqrt{\varepsilon} \quad (4)
\]

In (1), L represents the inductance and C represents capacitance. As L and C increase, the phase velocity \( V_p \) decreases; thus demonstrating the ‘Slow Wave Effect’. As \( V_p \) decreases, the guide wavelength \( \lambda_E \) decreases too as shown in (2). As \( \lambda_E \) decreases, the effective
permittivity $\varepsilon$ increases as in (3). Here, $\lambda$ is the free space wavelength. This increases in $\varepsilon$ leads to miniaturization of the device. The idea of EBG structure formulation is to increase the $L$ and $C$ such that the phase velocity $V_p$ is lowered while maintaining the ratio $L/C$ so that the characteristic impedance $Z_0$ as represented by (4) is not disturbed.

The size of the power divider is $31 \text{ mm} \times 16 \text{ mm} = 496 \text{ mm}^2$.

Fig. 1 : Conventional in-phase hybrid-ring equal power divider

**II. THE TILE EBG STRUCTURE**

In this paper, a new type of EBG structure termed the ‘Tile EBG’ is presented. Fig. 2 shows the new EBG structure.

![Tile EBG Unit Cell](image)

As the gap ‘c’ is increased the capacitance due to this gap decreases shifting the operating frequency to the higher side. Increase in the gap ‘d’ also shifts the operating frequency to the higher side. The dimensions of rectangular metal components of the Tile EBG are represented by ‘a’ and ‘b’. As ‘a’ is increased while maintaining ‘c’ and ‘d’ constant, the effective inductance of the structure increases shifting the operating frequency towards the higher side.

**III. PROPOSED POWER DIVIDER**

Fig. 3 shows the proposed power divider layout. The dimensions of EBG cells used between port 2 and 3 are as follows: $a = 0.7 \text{ mm}$, $b = 0.3 \text{ mm}$, $c = 0.1 \text{ mm}$, $d = 0.2 \text{ mm}$. The dimensions of the EBG cells used between port 4 and 5 are: $a = 1.6 \text{ mm}$, $b = 0.7 \text{ mm}$, $c = 0.2 \text{ mm}$, $d = 0.3 \text{ mm}$.

The size of the proposed power divider is $18.7 \text{ mm} \times 12.8 \text{ mm} = 239 \text{ mm}^2$. Thus there is a size reduction of 51.8%.

![Proposed Power Divider](image)

**IV. RESULTS**

The layout was simulated in IE3D. The conventional hybrid ring power divider was also simulated in IE3D for comparison. Fig. 4 shows the simulated S parameters of the proposed power divider. $S_{21}$ at ports 2 and 3 is $-3.17$ dB at 4 GHz while the return loss $S_{11}$ is $-17.6$ dB at 4 GHz. Thus the power is divided equally at ports 2 and 3 and the power divider is well matched at 4 GHz.

![S11 and S21](image)

Fig. 5 shows the isolation between ports 2 and 3. $S_{32}$ at 4 GHz is $-16$ dB. Thus the ports 2 and 3 are well isolated.
Fig. 5 : S32 of the proposed power divider

Fig. 6 shows the VSWR of the conventional and proposed power divider. From this graph, the bandwidth of conventional power divider is 216 MHz and that of proposed power divider is 236 MHz. Thus there is an 8.5% increase in bandwidth. Higher bandwidth finds application is suitable for high speed data transfer applications.

V. CONCLUSION

A novel Tile EBG structure was used for designing the In Phase Hybrid Ring Power Divider. Size reduction of 51.8% is achieved using this structure. An 8.5% increase in bandwidth is observed. The proposed design is suitable for compact and broadband applications.

VI. REFERENCES


