Design of 10dB 90° branch line coupler using microstrip line with defected ground structure

Jong-Sik Lim, Chul-Soo Kim, Jun-Seok Park, Dal Ahn and Sangwook Nam

The authors present a 10dB 90° branch line coupler operating at 1.8GHz and having a defected ground structure (DGS), a kind of periodic structure realised by etching on the ground plane under the microstrip line. Owing to the additional effective inductance of the DGS, the characteristic impedance of the microstrip line is increased for the same width of conductor. The microstrip line of 150Ω of characteristic impedance with 1mm of conductor width is realised by adding the DGS, while 1mm corresponds to 82Ω of conventional microstrip line on the RT/Duroid 5880 substrate with 2.2 of dielectric constant and 31 mils of thickness. It is shown that a 90° branch-line 10 dB coupler has been fabricated using the 150Ω line with DGS. Its measured performances are in good agreement with the predicted results.

Introduction: In general, the characteristic impedance of realisable microstrip lines is limited at around 120–130Ω, despite the fact that it depends on the dielectric constant (ε_r) and thickness of the substrate (H). It is almost impractical to realise a conventional microstrip line having an impedance > 150Ω due to the extremely small aspect ratio (W/H) and dispersion. To overcome this limitation, a much wider microstrip line conductor is required for the same characteristic impedance value. Recently, transmission lines with a two-dimensional photonic bandgap (PBG) and one-dimensional defected ground structure (DGS) have been studied [1 – 4]. Etched defects on the ground plane of a microstrip line provide higher effective permittivity and characteristic impedance than those of a conventional microstrip line due to their additional effective inductance [3, 5]. Microstrip lines with DGS exhibit an increased group velocity delay due to the steep phase characteristic. A delay in the group velocity contributes to a reduction in the size of the distributed components in RF and microwave circuits.

Conventionally, 90° branch-line couplers have been widely used to obtain typical coupling such as 3 or 6dB. A 10dB branch line coupler can only be used to a very limited extent in conventional microstrip configurations because it requires a very thin microstrip line with a characteristic impedance of > 150Ω. In this Letter, a novel 90° branch-line coupler with DGS is proposed in order to implement loose coupling and to investigate usefulness of the new microstrip line with DGS.

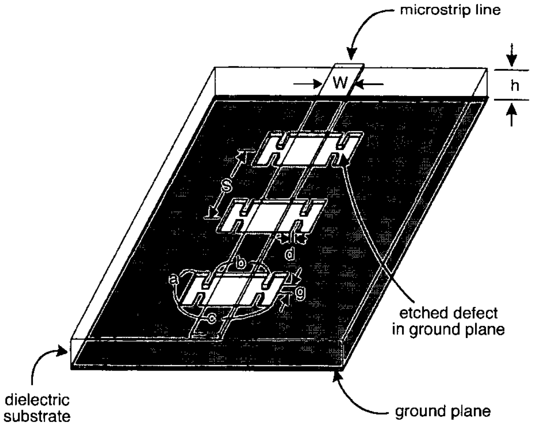

Fig. 1 *Three-dimensional view of proposed microstrip with DGS patterns*

S = 8mm, a = b = 6mm, c = 13mm, d = 2mm, g = 0.5mm

Quarter-wave transmission lines with DGS for the design of 10dB branch line coupler: A branch-line coupler with 10dB coupling needs quarter-wave transmission lines with characteristic impedances of 150 and 47.4Ω. It is very difficult to realise a 150Ω transmission line while retaining the reasonable aspect ratio of a conventional microstrip. In this work, the microstrip line with DGS shown in Fig. 1 is used to realise a 150Ω transmission line.

This DGS microstrip line was analysed by electromagnetic simulation to find its characteristic impedance. Fig. 2 shows the simulated S-parameters for the microstrip line with DGS patterns. The characteristic impedance is determined from the simulated results shown in Fig. 2, simple transmission line theory using Fig. 3 and eqns. 1 – 3. A simplified version of the DGS transmission line is shown in Fig. 3. When $\theta = \pi/2$ at the design frequency, the magnitude of the reflection coefficient (Γ) is maximised and the input impedance (Z_{in}) has the first maximum value. Using eqn. 1, Γ can be easily calculated. Eqn. 2 and eqn. 3 give the characteristic impedance (Z_D) of the DGS microstrip line, i.e. 150Ω. S_{21} shows a cutoff frequency at 4.0GHz due to the increased effective inductance, which enables a much higher impedance than that of a conventional microstrip to be obtained for the same conductor width.

$$S_{11}\,[\mathrm{dB}] = 20\log|\Gamma| \tag{1}$$

$$Z_{in} = Z_o\frac{1+|\Gamma|}{1-|\Gamma|} \tag{2}$$

$$Z_D = \sqrt{Z_{in}Z_o} = Z_o\sqrt{\frac{1+|\Gamma|}{1-|\Gamma|}} \tag{3}$$

An RT/Duroid 5880 substrate with a dielectric constant of 2.2 and a thickness of 31 mils was used. The quarter wavelength and conductor width of the 150Ω line with 1D periodic DGS are 26 and 1mm at 1.8GHz, respectively, while those of a conventional microstrip are 31 and 0.2mm. It should be noted that the conductor width of a 150Ω DGS microstrip line is 1.0mm, whereas 1mm corresponds to an 82Ω line on a conventional microstrip line. Thus, five times magnification of the conductor width has been achieved by employing a DGS on the ground plane.

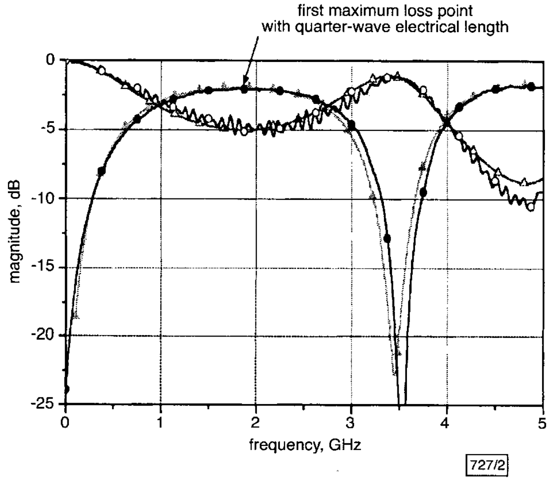

Fig. 2 *Simulated and measured results of proposed microstrip line with DGS patterns*

a Simulation
△ *S*11
- -△- - *S*21

b Measurement
—●— *S*11
—○— *S*21

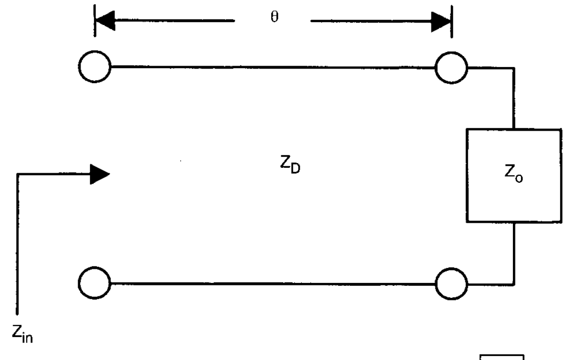

Fig. 3 *Simplified DGS transmission line for finding input impedance by terminating with* Z_o

Measured results and discussions: We have designed and fabricated a 90° branch-line coupler with 10dB coupling using a 150Ω DGS microstrip line at 1.8GHz. EM simulation was performed by the finite element method using HFSS. The predicted performances are shown in Fig. 4*a*, while the measured results are depicted in Fig. 4*b*. It can be seen that 0.5dB of through and 10.4dB of coupling were measured at the design frequency. The measured return loss and isolation are less than –25dB. All the measured performances agree well with the simulated results. This agreement means that the proposed DGS microstrip line and 10dB coupler are justified. To our knowledge, this is the first implementation of such a 10dB branch line coupler (9: 1 unequal power divider) using MIC fabrication technology.

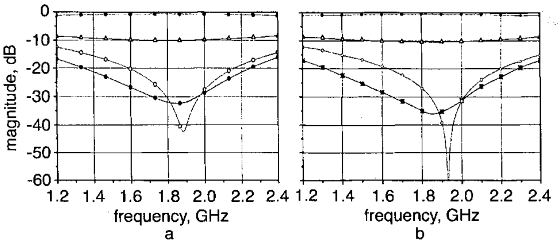

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Fig. 4 *Performances of fabricated branch line coupler with DGS section*

a Simulation	*b* Measurement
···◆··· through	—◆— through
—△— coupling	—△— coupling
—○— isolation	—○— isolation
—◆— return loss	—✳— return loss

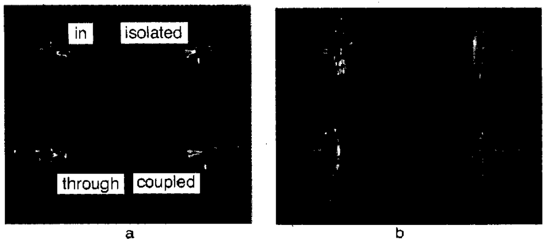

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Fig. 5 *Photograph of fabricated 90° branch-line coupler with DGS*

a Top view
b Bottom view

Another important issue associated with the proposed DGS coupler is its handling power capability. To handle high power, the conductor width of the microstrip line should be as wide as possible. Since DGS microstrip lines have a much wider conductor width than conventional lines for the same characteristic impedance, they can profitably be used in very high power applications.

Conclusions: We have designed and measured a novel 90° branch-line 10dB coupler with a new DGS microstrip line. Owing to the additional effective inductance of the DGS, a very high (> 150Ω) impedance line could be realised with a much greater conductor width. The measured 0.5dB of through and 10.4dB of coupling with excellent matching and isolation mean exact power coupling, i.e. power dividing by 9:1, and agree well with the predicted performances.

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Miniaturised 45° power divider using three-dimensional MMIC technology

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A miniaturised 45° power divider using three-dimensional MMIC technology is described. The divider comprises stacked thin-film microstrip lines that sandwich a ground plane between them. It has an area of only 0.43mm^2, and it exhibits a coupling of 4.5 ± 0.2dB and a phase difference of 45 ± 1° from 28 to 33GHz.

Introduction: Power combining and dividing with a phase shift is a useful technique for eliminating undesired signals, such as *n*th-order distortions, intermodulations, and images. Multifunction MMICs, such as single-chip receivers and transmitters, nowadays need to be extremely small, and one of the important issues in making such MMICs is reducing the size of the dividers and combiners they comprise. Three-dimensional (3D) MMIC technology using thin-polyimide-film layers (2.5μm each) on a wafer has been demonstrated to be very effective for this purpose [1].

A 45° power divider is one of the key components in a single-sideband (SSB) subharmonically pumped modulator (or mixer) [2 – 4], and its size can be reduced by using meander-like and stacked transmission lines above and below a ground plane. In this Letter we describe such a 45° power divider using 3D MMIC technology. There have been many reports about Wilkinson power dividers, 90° hybrids, and a 180° rat-race hybrid fabricated using 3D MMIC technology [5 – 9], but to the best of our knowledge there have been no reports of a 45° power divider fabricated using 3D MMIC technology.

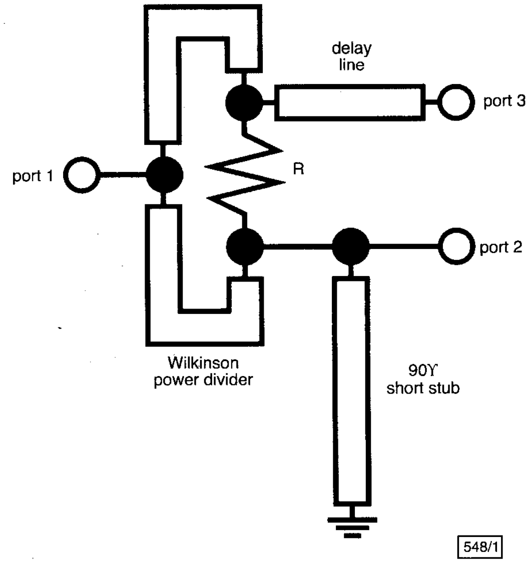

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Fig. 1 *Circuit configuration of miniaturised power divider*