# MINIATURIZED 90 DEGREE HYBRID COUPLER USING HIGH DIELECTRIC SUBSTRATE FOR QPSK MODULATOR

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## ABSTRACT

This paper describes miniaturized 90 degree hybrid coupler using edge-coupled microstriplines. A high dielectric constant substrate (K=38) and high-dense coupled-line configuration are adopted to realize small chip size. A conventional meandered coupled-line type and a new spiral coupled-line type were discussed for high-dense configuration. A bandwidth from 1.8 GHz to 3.6 GHz with $\pm 0.5$ dB power dividing balance and $90 \pm 3$ degrees phase difference were achieved with chip size of 1.5 x 1.5 mm.

## INTRODUCTION

A 90 degree hybrid coupler is a key component for the $\pi/4$ DQPSK modulation systems, because the phase error specification is very tight in digital communication systems and the 90 degree hybrid coupler in the modulator substantially determines the phase error of the transmitter. Since edge-coupled microstripline structure has an advantage of single planer configuration, it is much better in terms of low production cost than other designs such as Lange coupler[1] which requires air bridges or broadside coupler[2] which requires multi-layer configuration sensitive to coupling coefficient. A 900 MHz band hybrid coupler [3] and 2 GHz band hybrid coupler [4] using edge-coupled microstripline structure on K=21 substrate for digital mobile communication systems have been reported. These couplers are not small enough for multi-chip module (MCM) applications.

New 90 degree hybrid couplers for MCM applications with further miniaturization were developed. These one octave-band hybrid coupler are commonly suitable for the digital mobile radio systems using L-band. This paper describes about above mentioned 90 degree hybrid couplers: A conventional meandered coupled-line type and a new spiral coupled-line type were discussed for high-dense configuration.

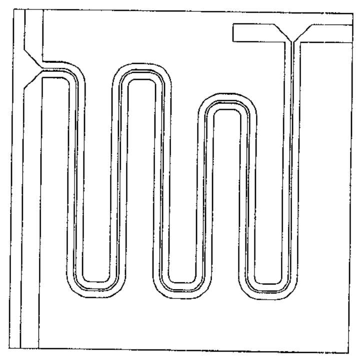

Figure 1. Meandered type 90 degree hybrid coupler

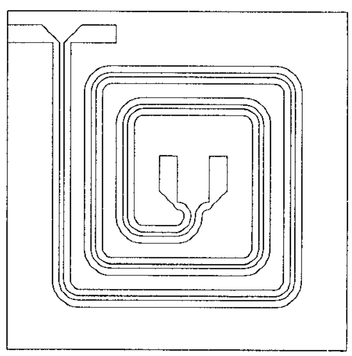

Figure 2. Spiral type 90 degree hybrid coupler





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## COUPLER DESIGN

The meandered coupled-line structure were applied for miniaturization of 90 degree hybrid coupler[3,4]. The meandered configuration is shown in Figure 1. This structure is extremely difficult to manufacture on high dielectric constant substrate because line width and spacing are very narrow. In this paper, a new spiral coupled-line structure is proposed for high-dense and tightly coupled configuration. The spiral configuration is shown in Figure 2. In the case of the spiral hybrid coupler, two I/O terminals are in the center of the chip. It requires wire bonding to connect external circuits to each terminals. The cross sectional representation of coupled-lines structure of the 90 degree hybrid coupler is shown in Figure 3. A 300 $\mu$ m thick and K = 38 dielectric ceramic substrate is used for miniaturization. The conductor width (**W**), the conductor gap (**G**) and the spacing between the neighboring pair lines (**S**) are the modeling parameters of simulation. High-dense coupled-line configurations make coupling between the adjacent pair lines closer. In the designing, the effects of microstripline configuration with narrow spacing between the adjacent pair lines were calculated using moment method simulator. These parameters were optimized to miniaturize the hybrid coupler without appreciable degradation in the electrical performance.

The electromagnetic field of the spiral configuration is different from the electromagnetic field of the meandered one. The field distribution of the both configurations are shown in Figure 4 and Figure 5. In the case of meandered configuration, because even mode current is opposite direction in the adjacent coupled-line, two coupled-lines are coupled in even mode. In the case of spiral configuration, because even mode current is the same direction in the adjacent coupled-line, two coupled-lines are not coupled in even mode at all. Then a characteristic impedance of even mode meandered coupled-line is smaller than even mode spiral coupled-line. Therefore coupling coefficient of spiral coupled-line is tighter than meandered one. The spiral coupled-line structure have a feature that the degradation in electrical performance is smaller than the meandered coupled-line structure by selected small spacing **S**. The physical dimensions of the both configurations are shown in Table 1. The spiral configuration does not require narrower gap and wider spacing, which are suitable for precise and high-dense machining.

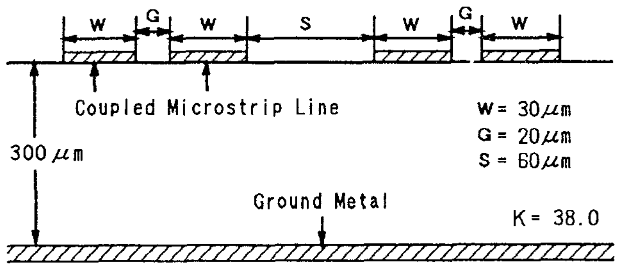


Figure 3. The cross sectional view of the 90 degree hybrid coupler

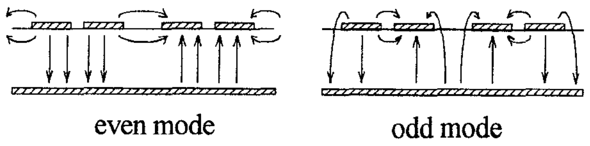


Figure 4. Field distribution of meandered configuration

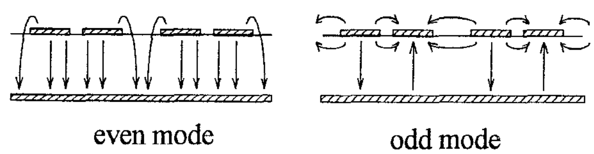


Figure 5. Field distribution of spiral configuration

Table 1. Physical dimensions of the hybrid couplers

| Parameters | Meandered type | Spiral type |
|---|---|---|
| W | 30 $\mu$ m | 30 $\mu$ m |
| G | 10 $\mu$ m | 20 $\mu$ m |
| S | 120 $\mu$ m | 60 $\mu$ m |
| Line length | 6.5 mm | 7.5 mm |
| Substrate thickness | 300 $\mu$ m | 300 $\mu$ m |
| Chip size | 1.5 x 1.5 mm | 1.5 x 1.5 mm |

## COUPLER FABRICATION

The 90 degree hybrid coupler was fabricated on a polished 300 $\mu$ m thick dielectric ceramic substrate of K=38. The high dielectric constant substrate of $(ZrSn)TiO_4$ system was used, which has high Q value of 30,000 at 2 GHz and small temperature coefficient of dielectric constant of 0 to 1 ppm/degree C [5].

A semi-additive patterning method is applied for construction of coupled-line configuration. The device construction starts with the deposition of a thin metal layer of Ti-Pd. Next, couple-line configuration is shaped by photolithography and electroplating process of which metal is Au. The elctroplating process makes so enough thickness of an electrode that electrical characteristics are free from effect of thickness variation.

## EXPERIMENTAL RESULTS

The fabricated chip of the 90 degree hybrid coupler are die-bonded and wire-bonded to a testfixture as shown in Figure 6 and measured. The calculated and measured frequency characteristics of the meandered type coupler and the spiral type coupler are shown in Figure 7 and Figure 8. The spiral type coupler has a broad band characteristics of amplitude balance and phase difference compared with the meandered type. It achieved the bandwidth from 1.8 GHz to 3.6 GHz with a maximum amplitude variation of $\pm 0.5$ dB. The phase difference between the direct port and the coupled port was $90 \pm 2$ degrees up to 4 GHz. The measured performances agree well with the calculated S-parameters using the moment method simulator.

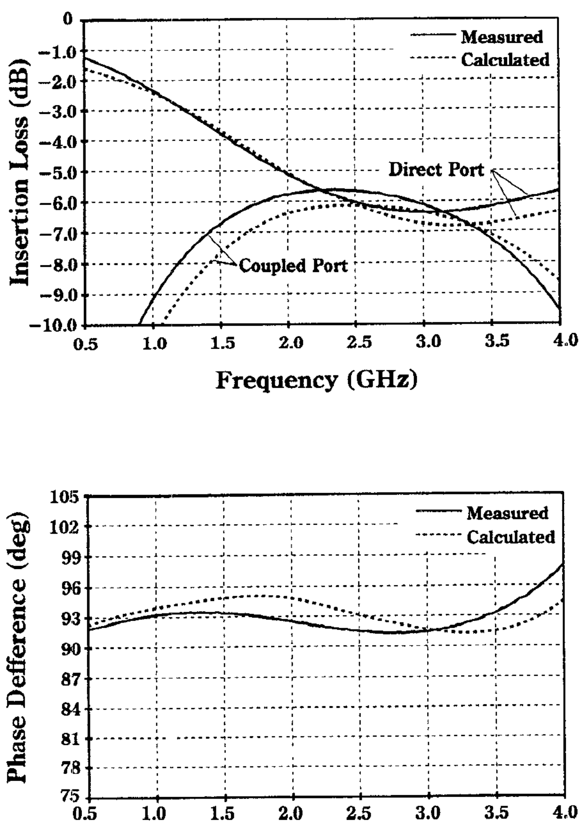


Figure 7. Frequency characteristics of the meandered type coupler

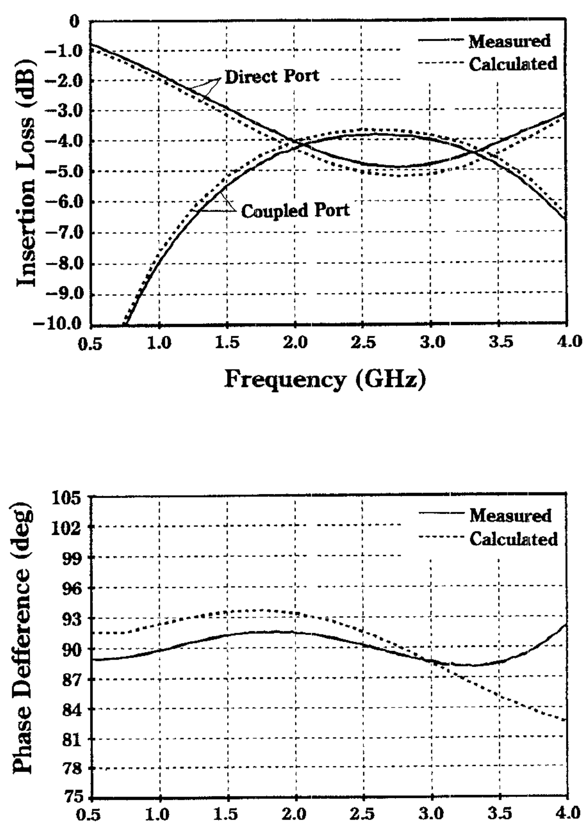


Figure 8. Frequency characteristics of the spiral type coupler

The measured electrical performances of the both 90 degree hybrid couplers are summarized in Table 2. Photographs of the both type 90 degree hybrid coupler chips are shown in Figure 9 and Figure 10. The chip size of the both hybrid couplers is 1.5 x 1.5 mm.

## CONCLUSION

The further miniaturized 90 degree hybrid couplers by one forth compared with conventional one were developed and high-dense coupled-line configurations using high dielectric constant substrates were discussed. The conventional meandered type and the new spiral type coupled-line structure with narrow spacing between neighboring pair lines were designed using moment method simulator. The experimental results of the spiral type coupler was superior to the meandered type one. With its advantages of broad band operation, precise phase error, further miniaturized chip size, this 90 degree hybrid coupler should have many MCM applications in direct QPSK modulators.

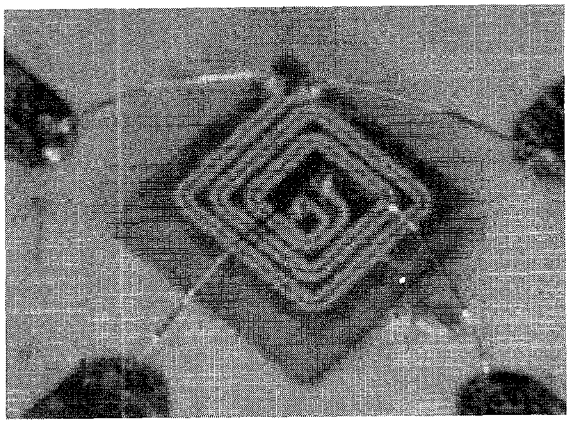

Figure 6. Photograph of the wire-bonded coupler chip

Table 2. Electrical performances of the hybrid couplers

| Configuration | Meandered type | Spiral type |
|---|---|---|
| Frequency | 1.8 - 3.6 GHz | |
| Insertion loss | 4.5 - 7.5 dB | 3.8 - 5.0 dB |
| Amplitude balance | $\pm$0.7 dB | $\pm$0.5 dB |
| Phase difference | 93$\pm$2 degree | 90$\pm$2 degree |
| Return loss | 15 dB min. | 15 dB min. |

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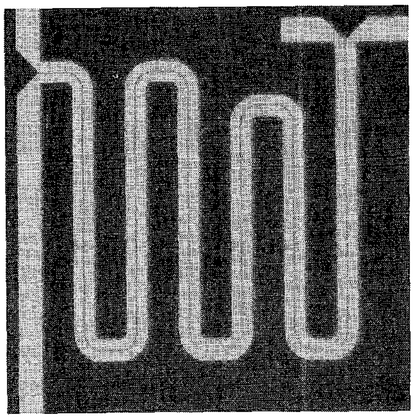

Figure 9. Photograph of the meandered type coupler

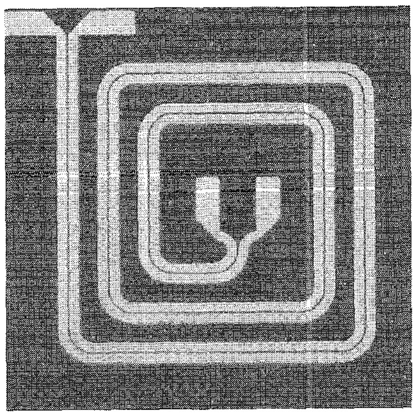

Figure 10. Photograph of the spiral type coupler