Slotline Annular Ring Elements and Their Applications to Resonator, Filter and Coupler Design

Chien-Hsun Ho, Lu Fan and Kai Chang

***Abstract*—A slotline type of annular ring element has been developed as a new circuit component for resonator, filter, and hybrid coupler applications. Various coupling methods were devised for the use of this slotline ring in many applications. A new type of slotline dual-mode filter has been developed with a bandwidth of 12.3% and a stopband attenuation of more than 30 dB at the center frequency of 3.5 GHz. Another slotline type of cross-over hybrid ring coupler which utilized a slotline T-junction and a resistively-coupled slotline ring has also been developed with a bandwidth of more than 80%, an excellent power dividing balance of ± 0.2 dB, and a fairly good isolation of 35 dB. With the ease of adding series and shunt components, the slotline annular ring element should have many applications for MICs and MMICs.**

I. Introduction

The microstrip annular ring element has been widely used as a resonator for measurements [1] and a building component of bandpass filters [2]. Other attractive applications based on the microstrip ring have also been published [3]–[5]. However, the inconvenience of adding tuning components limits the applications of the microstrip ring structure. This paper presents slotline annular ring circuit components that have characteristics similar to those of the microstrip ring, but with the advantages of better performance and easy integration with series and shunt solid-state devices. Little work has been reported for these slotline ring components [6], [7].

The second section of this paper discusses the design techniques for the slotline ring resonators with CPW, microstrip, or slotline feeds. Filter designs using dual resonant modes are investigated in the third section. The fourth section illustrates the designs and applications of the slotline hybrid ring couplers. The circuit analyses for the slotline ring circuits were based on simple transmission line circuit models. The measured results agree with the theoretical predictions very well.

II. Slotline Ring Resonators

Coupling between the external feedlines and slotline ring can be classified into the following three types: (1) microstrip coupling, (2) CPW coupling, and (3) slotline coupling. Fig. 1 shows these three types of coupling schemes. The resonant frequencies of the slotline ring resonator are determined by

$$2\pi r = n\lambda_s \quad (1)$$

where r is the mean radius of the slotline ring, λ_s is the slotline guide wavelength, and n is the mode number.

Fig. 2(a) shows the comparison of measured and calculated frequency responses of insertion loss for a microstrip-fed slotline ring resonator. The theoretical results were calculated from the equivalent transmission line circuit model [8]. The lengths of input and output microstrip coupling stubs, as shown in Fig. 1, can be adjusted to optimize the loaded Q values. The CPW-fed slotline ring resonator has similar characteristics to those of the microstrip-fed slotline ring resonator. Fig. 2(b) shows the theoretical and experimental results for the slotline ring resonator with slotline feeds. The capacitive couplings of the CPW- or microstrip-fed slotline ring resonator become more efficient at higher frequencies. However, the coupling

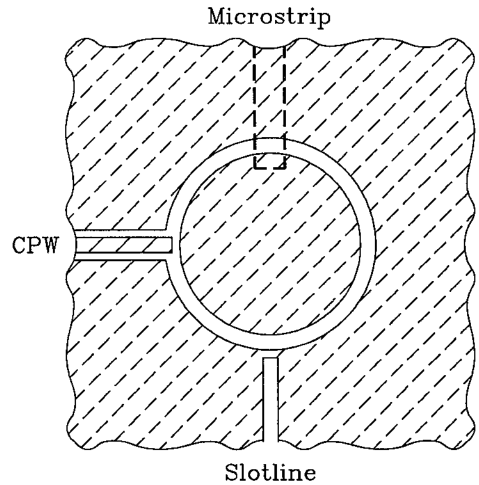

Fig. 1. Circuit configuration of the slotline ring resonator with different coupling schemes.

of the slotline-fed ring resonator is inductive and becomes less efficient at higher frequencies as shown in Fig. 2(b). The inductively coupled slotline ring resonator has the dual characteristics of the capacitively coupled slotline ring.

III. Slotline Dual-Mode Bandpass Filters

The resonant modes with odd mode numbers cannot exist in the asymmetrically coupled ring structure due to mode splitting. However, by applying perturbation symmetrically at 45° or 135°, the dual resonant modes can be excited [2]. The same dual-mode characteristic can also be found in a slotline ring structure with the perturbation of backside microstrip tuning stubs.

By using microstrip tuning stubs on the back side of an asymmetrically coupled slotline ring at 45° and 135°, the dual resonant modes can be excited. Fig. 3 shows the circuit configuration of the slotline dual-mode bandpass filter. The microstrip feed-lines located at 0° and 270° are used to extract both sine and cosine resonant modes which are orthogonal to each other in the ring structure. Fig. 4 shows the measured frequency responses of insertion loss and return loss for a slotline dual-mode bandpass filter with mode number $n = 3$. The dual-mode filter has a 12.3% bandwidth at the center frequency of 3.5 GHz, a stopband attenuation of more than 30 dB, and a sharp gain slope transition. Compared with the microstrip dual-mode filter, the slotline dual-mode filter has a better in-band performance and the advantage of flexible tuning.

IV. Slotline Cross-Over Hybrid Ring Couplers

The microstrip cross-over hybrid ring coupler has been introduced with a $\lambda/4$ cross-over branch-line for the replacement of the $3\lambda/4$ phase delay section of the conventional microstrip rat-race hybrid ring coupler [8]. This paper presents a new slotline type of cross-over hybrid ring coupler. This new coupler simply consists of a slotline T-junction and a resistively-coupled slotline ring. The design technique substitutes one reverse-phase slotline-T junction for the conventional rat-race phase delay section. Since the phase reversal of the slotline-T junction is frequency independent, the resulting slotline ring coupler has a broad bandwidth. Fig. 5 shows the circuit layout of the slotline cross-over hybrid ring coupler. The impedance of the

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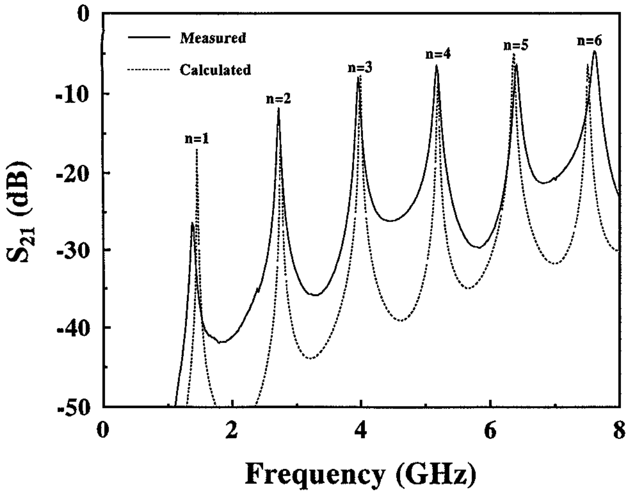
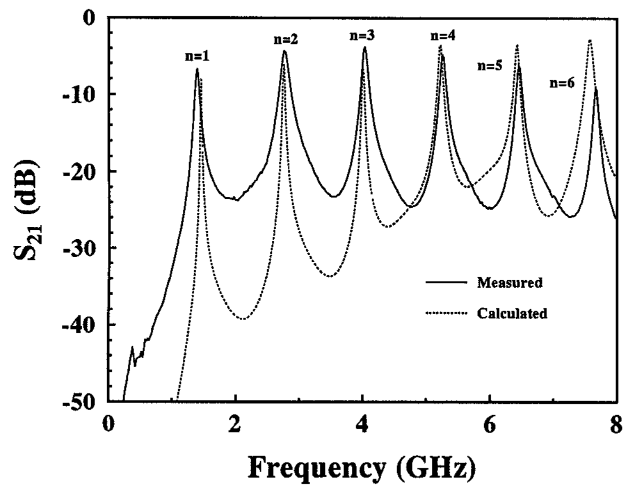


(a)



(b)

Fig. 2. Measured and calculated frequency responses of insertion loss for slotline ring resonators with (a) microstrip feeds and (b) slotline feeds.

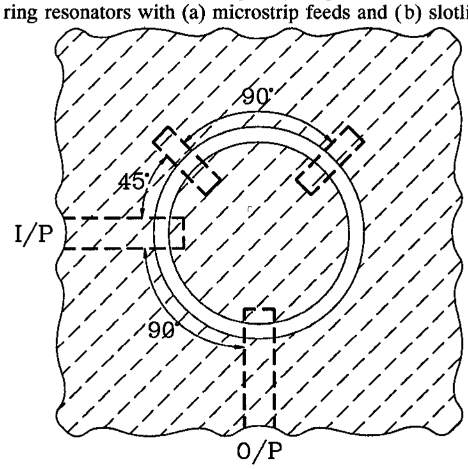


Fig. 3. The slotline dual-mode filter configuration.

slotline cross-over hybrid ring coupler is given by

$$\frac{Z_s^2}{Z_m^2} = 2N^2 \tag{2}$$

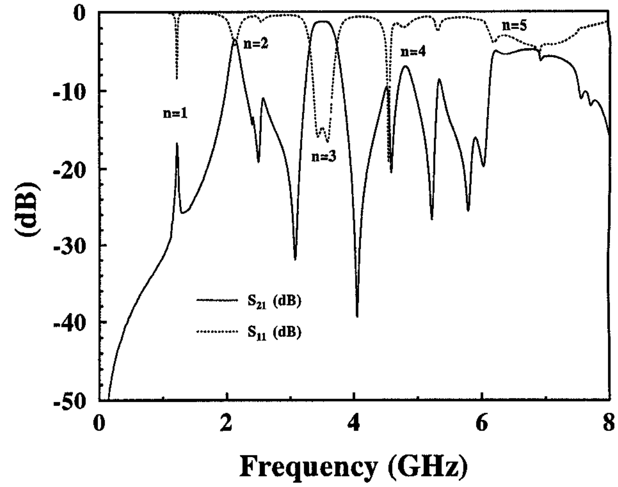


Fig. 4. Measured frequency responses of insertion loss and return loss for a slotline dual-mode filter with backside microstrip tuning stubs at 45° and 135°.

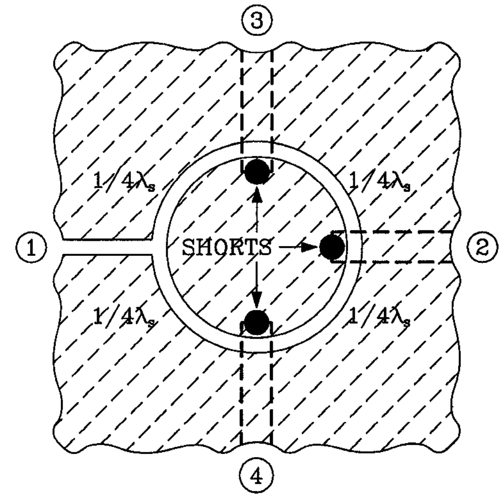


Fig. 5. The slotline cross-over hybrid ring coupler configuration.

where N is the turn ratio of the equivalent transformer determined by [8]. The radius of the slotline ring is determined by

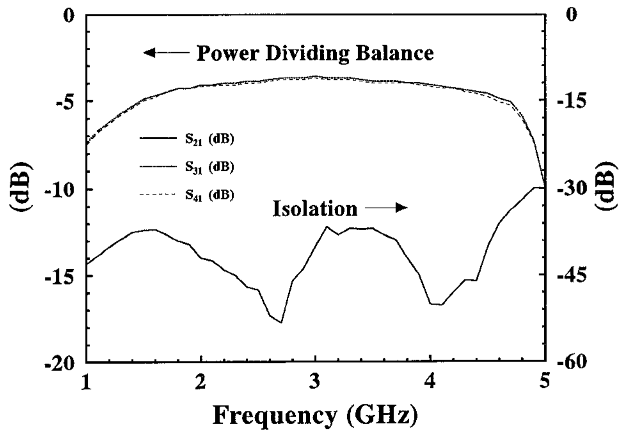
$$2\pi r = \lambda_s \tag{3}$$

where λ_s is the guide wavelength of the slotline ring.

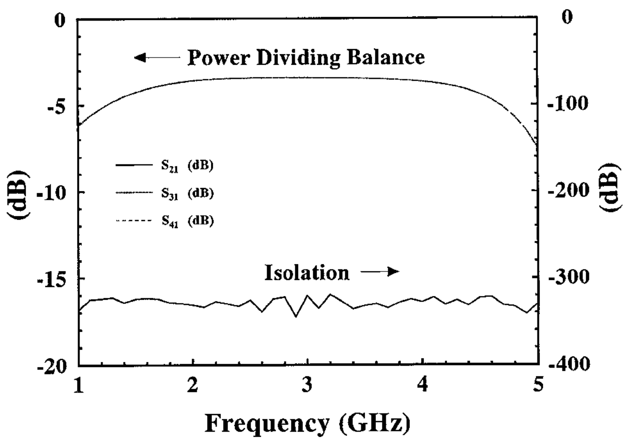
Fig. 6(a) and (b) show the measured and calculated results of a slotline cross-over hybrid ring coupler. Figure 6(a) shows that the new coupler has an excellent isolation of greater than 35 dB and a good power dividing balance of ± 0.2 dB over an 80% bandwidth. The measured and calculated results shown in Fig. 6(a) and (b) agree very well.

V. Conclusions

Slotline types of annular ring elements have been developed as circuit components for the resonator, filter, and hybrid coupler. Various coupling methods were devised for different applications. A slotline dual-mode filter and slotline cross-over hybrid ring coupler were also demonstrated. The slotline annular ring element with the advantages of good performance and ease of adding series and shunt components should have many applications in hybrid and monolithic integrated circuits.



(a)



(b)

Fig. 6. Insertion loss of a slotline cross-over hybrid ring coupler; (a) measured results and (b) calculated results.

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A Low Noise, Phase Linear Distributed Coplanar Waveguide Amplifier

K. Minot, B. Nelson, and W. Jones

Abstract—**Details of the design, fabrication, and measured data for an InGaAs high electron mobility transistor (HEMT) decade-bandwidth distributed coplanar waveguide (CPW) amplifier are presented. Comparison to a similar microstrip design is made. The design methodology highlights described here include CPW transmission line loss modeling. The circuit features the best reported CPW distributed amplifier noise figure and phase performance over 2–20 GHz as well as an on-chip bias network and low dc power consumption. The minimum measured noise figure is 2.1 dB with 11 dB maximum gain. The measured phase linearity is less than ±5° over 2–20 GHz which makes this circuit well suited for system phased array applications where phase matching and linearity are a primary concern.**

I. Introduction

Advances in space and ground communication technologies are pushing the limits of such system requirements as size, weight, and performance. There is a constant desire to produce the smallest, lightest unit with the most outstanding performance yet seen over a broad bandwidth of frequencies. Phase linearity and chip to chip phase matching are becoming increasingly more critical system performance characteristics. As a result, the distributed amplifier (DA) has become an ideal topology choice for subsystem phased array elements requiring signal amplification [1]–[3]. Not only does the distributed topology offer typically greater than octave bandwidth performance, but it also offers excellent phase linearity due to the transmission line characteristics inherent in its topology. A DA is made up of a set of cascaded devices, which act as shunt capacitance, connected together by high impedance transmission lines that simulate inductance. A distributed transmission line constructed as such will have a near constant group delay and, hence, low phase deviation from linear below the cutoff frequency of the artificial transmission line.

In addition to the phase linear properties of the DA structure, we present a design for which simplified processing and system use are also advantages. This CPW design requires no vias or backside gold processing during wafer fabrication since the ground plane is entirely on the top surface of the circuit. Thus, all ground connections can be made from the top of the circuit when used in higher level system integration. This paper will describe CPW transmission line modeling, circuit design, fabrication, and performance of a 2–20 GHz CPW DA.

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