the Fano resonance on substrate integrated waveguides

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Abstract——**In this paper, we propose two novel structures which induce Fano resonance with high quality factor based on substrate integrate waveguide at micowave frequency . First structure is composed of one-half of a circular substrate integrated waveguide and a metal rectangular cavity. The Fano resonance occurs in the pass band of the waveguide integrated waveguide.The second is a rectangular substrate integrated waveguide which coupled with split rings. The Fano resonances were studied and verified by numerical simulation.**

Keywords—substrate integrated waveguide; the rectangular cavity; Fano resonance; the transmission spectrum; asymmetrical line-shape

I. INTRODUCTION

Fano resonances is a resonance discovered by Ugo Fano[1] with distinct asymmetric line shape. The Fano resonance is a phenomenon in which the narrow-band discrete resonance state and a wide-band continuous state spectrum overlap with each other, and the destructive interference occurs between the two, so that the transmission spectrum exhibits an asymmetrical linear effect[2]. In metal nanoparticles, Fano resonance has a high degree of sensitivity to the optical properties of the surrounding medium and to the geometry of the metal nanostructure. At the same time, Fano resonance also features high quality factor. Based on the above advantages, Fano resonance has a wide range of applications[3]. In recent years, many researchers have conducted intensive research on Fano resonance. It has been shown that Fano resonances could occur in various plasmonic nanostructures, incuding nano-slits[4], ring-disk cavities[5], eta. Fano resonances also could be tuned by controlling the geometrical parameters of sub-wavelength structures structures[6-10]. Interference between different optical paths, the metal-medium-metal plasma composite cavity can induce Fano resonance, In the optical frequency and terahertz band, the dark resonance mode of Fano significantly reduces the radiation loss of the system. On the surface of the terahertz metamaterials, a periodic mirror-symmetrical open ring is integrated to realize an ultra-high sensitivity sensor[11]. Although Fano resonance has excellent characteristics, the above studies are usually based in the optical frequency, near infrared and terahertz bands .The quality factor of the Fano resonances is low.

In this paper, a one-half circular substrate integrated waveguide(CSIW) capable of exciting Fano resonance is proposed which has high quality factor. The transverse magnetic (TM) wave supported by the one-half CSIW is used to excite the mutual interference between the broadband bright mode and the narrow-band dark mode excited by the metal rectangular cavity. Hence the Fano resonance with high resonance intensity and high quality factor is realized. In addition, the groove rectangular substrate integrated waveguide (RSIW) coupled with split rings is also proposed to excite Fano resonance. The work will make Fano resonance more widely used in the low frequency range.

II. STRUCTURE DESIGN AND IMPLEMENTATION PRINCIPLE

A. *Fano Resonance Based on One-half Circular Substrate-Integrated Waveguide*

The schematic diagram of the proposed one-half circular SIW coupled gape with metal rectangular cavity is shown in Fig. 1(a). The SIW consists of three parts: metal, dielectric and metal ground. A semicircular copper is attached to the substrate Rogers RO5880 and connected to the metal ground via a metal cylinder. From Fig.1(b), compared with the solid black line for only one half of the CSIW, we can see a sharp Fano resonance for the the CSIW with different *g*. *g* is the distance of the metal rectangular cavity from the circular SIW. The simulated resonant frequency is 11.31 GHz and the intensity is 24.7 dB. The calculated quality factor is 420. When we change g, the resonant frequency changes as shown Fig.1(b). The bigger the distance is, the lower the resonant intensity is,So is for the resonant frequency. This result occurs, since the coupling between the one-half CSIW and the metal rectangular cavity weakens when the distance increases.

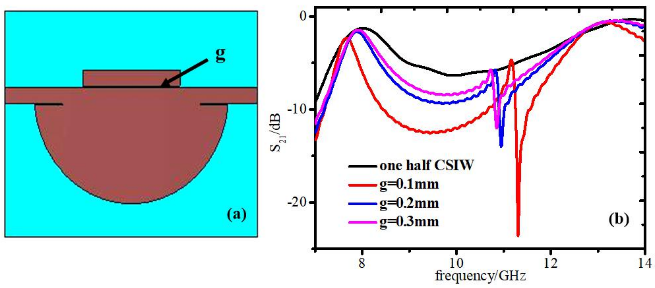

Fig.1(a) Schematic diagram of the proposed one-half circular SIW coupled with metal rectangular cavity. (b) The simulated S_{21} of the proposed structure.

B. Fano Resonance Based on Substrate Integrated Waveguide with Semi-circular Slot Line

Next, we engrave a semicircular slot line on the one-half CSIW, as shown in Fig. 2(a). Compared with the results in Fig. 1(b), it shows the resonance frequency of the structure has been decreased to 9.85GHz, and the resonance intensity increases (是提高了吧？) by 5.1 dB. This is because the semicircular slot line introduces an effective coupling capacitance, which results in a decrease in the resonant frequency

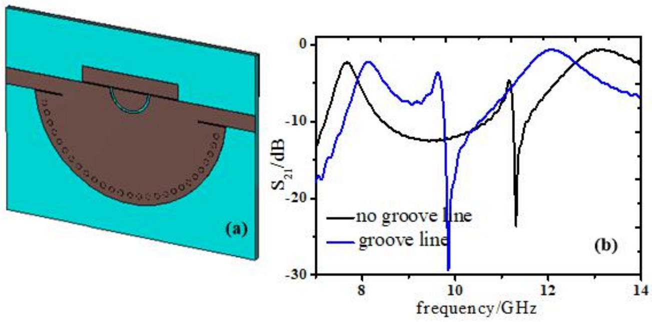

Fig.2(a) Perspective view of the one-half CSIW engraved with a semicircular slot line with a rectangular cavity of metal. (b) The simulated S_{21} of one-half CSIW coupled with metal rectangular cavity and the one-half CSIW engraved with a semicircular slot line with a rectangular cavity of metal.

C. Fano Resonance Based on Groove Rectangular Substrate-Integrated Waveguide Coupled with Split Rings

Fig. 3(a) shows the three-dimensional structure of rectangular SIW(RSIW) coupled with split rings. The RSIW and the split resonance ring (SRR) are interfered to form an asymmetric linear resonance. Fig. 3(b) shows the transmission spectrum of this proposed structure. The blue solid line is S_{21} of the RSIW at frequency from 3.5 GHz to 5 GHz. Compared to the blue line, the red line represent the Fano resonance due to the coupling between RSIW and SRR. The resonance frequency and intensity of Fano resonance is 4.26 GHz and 23.06 dB, respectively. The calculate quality factor is 1930. Numerical simulation results show that the structure can stimulate the Fano resonance of high quality factor.

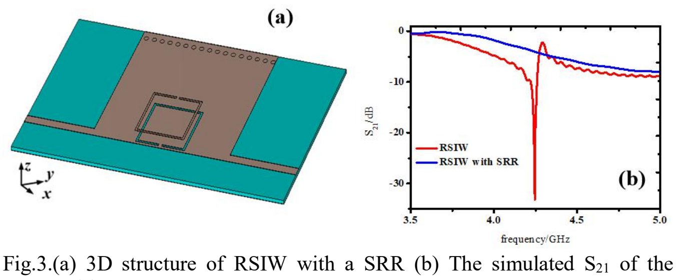

Fig.3.(a) 3D structure of RSIW with a SRR (b) The simulated S_{21} of the RSIW with SRR.

III. CONCLUSIONS

In this paper, Fano resonances based on substrate integrated waveguides has been studied. Two novel structures which induce Fano resonance with high quality factor have been proposed at micowave frequencies. Numerical simulation results show that the structures can stimulate the Fano resonance of high quality factors.

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