A Design of Amplifier using Harmonic Termination Matching Tuner and Harmonic Blocking Bias Line

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Abstract —In this paper, a new 3dB branch line hybrid using asymmetric defected ground structure (DGS) microstrip is proposed. The proposed branch line suppresses the 2nd and the 3rd harmonic component effectively. If transmission line having the arbitrary electrical length is connected at the through and the coupled port of DGS branch line hybrid, then DGS branch line hybrid is operated as impedance transforming tuner. Also a new DGS λ/4 bias line that can suppress high frequency harmonics as well as low frequency intermodulation is proposed. With harmonic termination tuner using the proposed hybrid and harmonic blocking bias line, the 2nd and the 3rd harmonic components of the fabricated amplifier that operated in IMT-2000 band were suppressed up 25dB and 27dB respectively. Harmonic load-pull setup of amplifier can be easily accomplished with proposed circuits.

I. Introduction

Recently harmonic load-pull amplifiers gain importance because such setups allow us to obtain the appropriate harmonic terminations for a transistor in order to obtain high efficiency and high linearity. And also harmonic load-pull can make the verification of transistor model. However, the active load-pull system that is widely used is very complicated and there are many difficulties in measurement [1][2].

Impedance tuner that transforms 50Ω termination impedance into the arbitrary impedance can be realized with 3dB hybrid and open or short stub in the coupled and the through port of 3dB hybrid. When an isolation port was 50Ω terminated, a reflection coefficient of the input port is easily controlled by changing stub lengths (θ_1, θ_2) in the coupled and the through port of 3dB hybrid, and expressed as below [3].

$$S_{11} = (e^{-j\theta_1} - e^{-j\theta_2})/2$$

Impedance tuner is used to measure the optimum input/output impedance of microwave circuit such as amplifier, mixer and so forth. Fig. 1 shows a conventional impedance tuner using 3dB hybrid and short stubs for optimum input/output impedance transformation.

When matching points of device under test (DUT) are measured with impedance tuners, the load-pull measurement in the operating frequency band is possible,

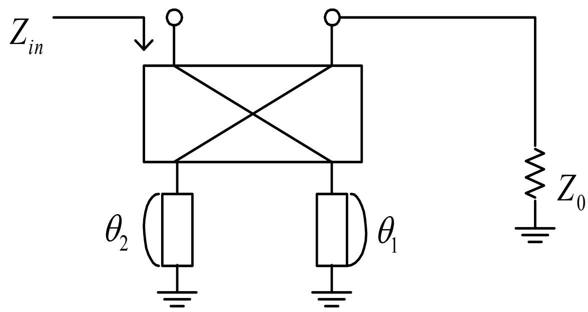


Fig. 1 Impedance tuner using 3dB hybrid and short stubs.

but harmonic termination is almost impossible due to the frequency characteristic of 3dB hybrid. So the operating condition in fundamental band can be changed due to harmonic terminating environment.

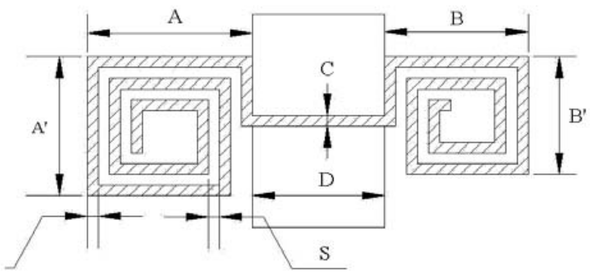
Defected ground structure (DGS), which is realized by etching dumbbell or spiral shaped patterns on the ground plane of microstrip line, has been proposed [4]. Several applications using DGS to design a coupler, filter and power amplifier have been already presented [5]-[7]. Recently DGS microstrip line that can suppress the 2nd and the 3rd harmonic by inserting asymmetric defect on ground plane have also been presented [8]. DGS microstrip provides slow-wave effect by increasing the effective inductance of the transmission line.

In this paper, an impedance tuner using a new 3dB branch line hybrid is proposed. Since the proposed 3dB branch line hybrid adopts asymmetric DGS microstrip lines, the 2nd and the 3rd harmonic can be easily suppressed. Also we use a λ/4 DGS bias microstrip that effectively suppress the 3rd harmonic component as well as the 2nd harmonic and low frequency intermodulation component. By adopting impedance tuner and λ/4 bias that suppress the 2nd and the 3rd harmonics in amplifier design, harmonic load-pull set-up of amplifier would be easily accomplished.

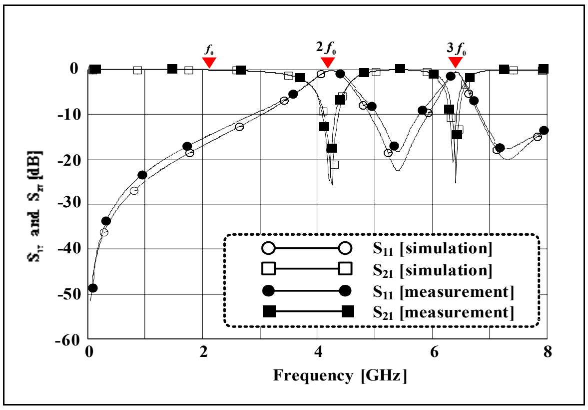
II. Harmonic Termination 3dB Branch Line Hybrid Tuner

Although there are several shapes in defect of DGS microstrip line, dumbbell or spiral shape is dominantly used. The spiral DGS microstrip line have steep band-rejection characteristic than dumbbell DGS line, but the bandwidth of band-rejection is narrower. Several stage dumbbell DGS line have also steep and wide band-rejection characteristic, the broader circuit size is required than the spiral. Therefore asymmetric spiral DGS that have a dual band rejection characteristic in the specified frequencies is effective for circuit size reduction.

Fig. 2 shows the geometry of an asymmetric spiral DGS on the ground plane of the microstrip line, in which the dimensions of the spiral-shaped defects in the right and the left side are different. And the transfer and the reflected characteristic are also shown. The used substrate is RT/duroid 5880 with the dielectric constant of 2.2 and thickness of 31mils and simulated with HFSS of Ansoft Co. Ltd. The asymmetric spiral DGS microstrip line is designed for IMT-2000 basestation transmitting band, the transfer characteristic around the 2nd and the 3rd harmonic band is suppressed.



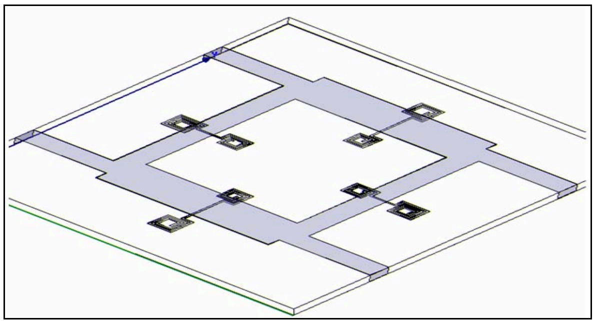
(a)



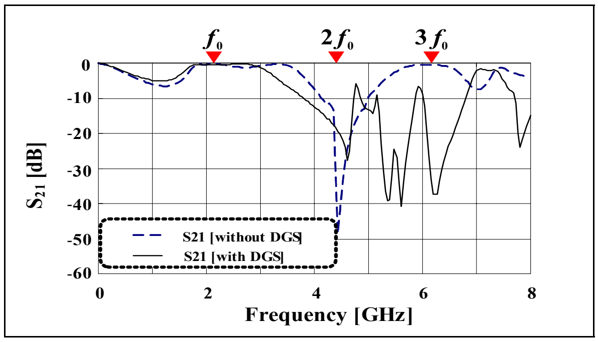
(b)

Fig. 2 (a) The asymmetric DGS microstrip line (A=3mm, A'=2.6mm, B=2.6mm, B'=2.2mm C/G/S=2mm, D=2.4mm), (b) the simulated and measured transfer and reflected characteristic.

Harmonic termination 3dB branch line hybrid using asymmetric DGS microstrip line is simulated and fabricated. The fabricated hybrid is slightly smaller size than the conventional hybrid because of slow-wave effect of DGS microstrip line. In conventional 3dB branch hybrid, length and width of 35.35Ω and 50Ω line are 26.8mm, 3.9mm and 26.4mm, 2.4mm respectively. But those of the proposed hybrid are 19.6mm, 5mm and 25.6mm, 2.4mm, respectively. Fig. 3(a) shows the geometry of the proposed branch line that the center frequency is 2.14GHz. The coupling and the transmitting coefficient of 3dB hybrid are -3.1dB and -3.4dB, respectively. Fig. 3 (b) shows the transfer characteristic in case of feeding open stub at the coupled and the through port having the same electrical length. For comparison, the electric characteristics of the conventional 3dB hybrid are also shown. The transfer loss at the operating band, the 2nd, and the 3rd harmonic are -0.3dB, -13dB and -25dB, respectively. The results at the operating band and the 2nd harmonic show very similar characteristics. But the characteristics at the 3rd harmonic are quite different. It is definitely observed that the 2nd and the 3rd harmonic can't pass in the proposed harmonic termination 3dB branch line hybrid.



(a)



(b)

Fig. 3 (a) The geometry of harmonic termination 3dB branch line hybrid, (b) the measured transfer characteristic of the conventional and the proposed hybrid.

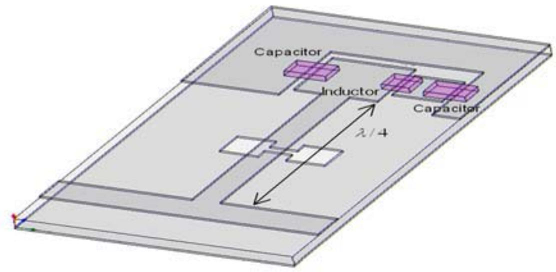
III. Harmonic Blocking Bias Circuit

Small signal amplifiers in UHF band usually adopt chip inductors as RF-choke for bias. But λ/4 high impedance transmission lines terminated with chip capacitor or radial stubs are usually used as bias line. When a capacitive-terminated λ/4 bias line is connected to signal line, even harmonic components that pass the signal line are blocked, while odd harmonic components pass the signal line.

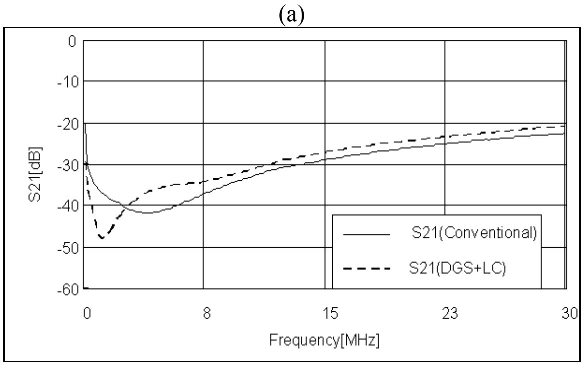
In amplifying signal process, amplifier generates harmonic and intermodulation distortion components in addition to the amplified input signal. A proper harmonic termination is required to increase the efficiency and for active loadpull setup.

Fig. 4 (a) shows the layout of harmonic blocking λ/4 bias line. Instead of conventional microstrip line, λ/4 DGS microstrip line is used. Due to slow effect of DGS, the 2nd pass-band is shift-down. As a result, the 2nd harmonic of the amplifier can be reflected at bias line junction point. Also bypass LC series resonating circuit is inserted in bias pad of λ/4 bias line in addition to the bypass capacitor [9]. This LC tank makes low frequency blocking range broader than without LC resonating circuit.

Fig. 4 (b) shows the transfer characteristics of the conventional and the proposed bias line in the low frequency band. The low frequency band-rejection of the proposed bias line is shift down, so that low intermodulation component can be reduced than the conventional bias line. Also the transfer characteristics of the conventional and the proposed bias line in the operating and harmonic band are shown in the Fig. 4 (c). The operating and 2nd harmonic frequency characteristic is almost similar to that of the conventional bias line, but



(a)



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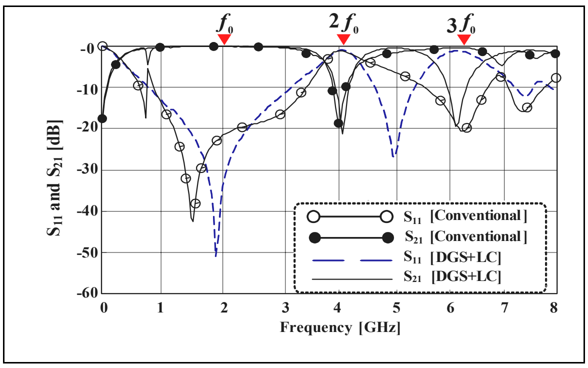


(c)

Fig. 4 (a) The layout of harmonic blocking λ/4 bias line, (b) the low frequency band transfer characteristic and (c) the wide frequency band transfer and reflected characteristic.

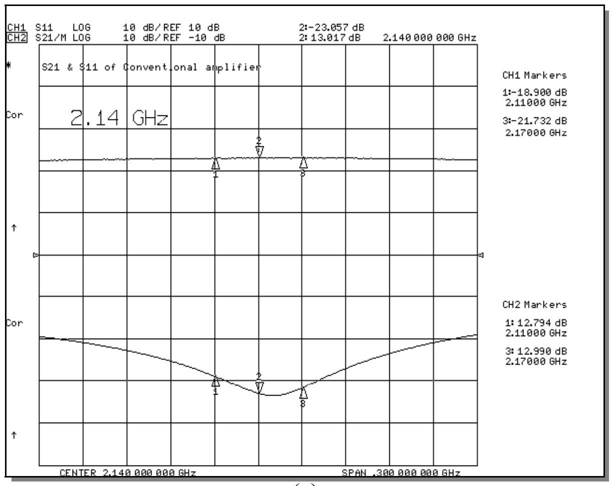
the 3rd harmonic band is shift down, so that the 2nd and the 3rd harmonic are blocked by the proposed bias line.

IV. Amplifier Design Using Harmonic Termination Tuner and Harmonic Blocking Bias Line

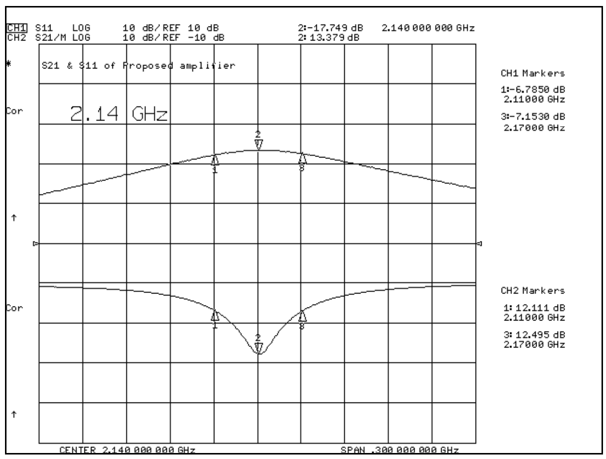
To show validity of the proposed harmonic termination impedance tuner and the harmonic blocking bias line, two kinds of amplifier are fabricated and compared. One is realized with the conventional bias line and only in-band matching circuits. The other is realized with the harmonic termination tuner and harmonic blocking bias line. The operating frequency is 2.11~2.17GHz and the used transistor is FLL357ME of Fujitsu.

Fig. 5 shows the transfer and reflected characteristic of the conventional and the proposed amplifier. The measured gain, the maximum return loss, and 1dB compression point (P_{1dB}) of the conventional are obtained 13.03±0.1dB, –23dB, and 35dBm, and those of the proposed are obtained 13.38±0.07dB, –17.75dB and 34dBm, respectively. These characteristics show similar electrical characteristics in operating band.

Fig. 6 shows the 2nd and the 3rd harmonic characteristics to the fundamental of two amplifiers. In suppression to fundamental are 36.40dBc and 36.26dBc,



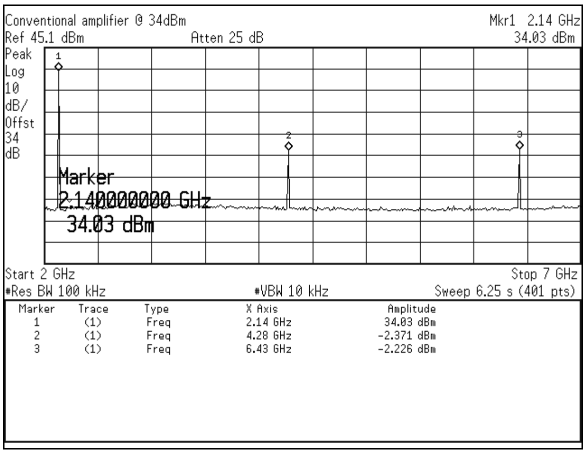
(a)



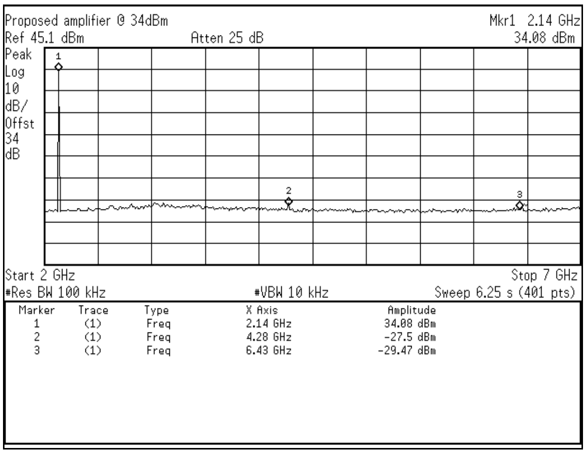
(b)

Fig. 5 The transfer and reflected characteristics of (a) the conventional and (b) the proposed amplifier.

while those of the proposed are 61.58dBc and 63.50dBc, respectively. It is noticeable that the 2nd and the 3rd harmonic component level of the proposed amplifier are quite smaller than those of the conventional. This means that the proposed bias and the proposed impedance tuner terminate harmonic components properly.



(a)



(b)

Fig. 6 The measured harmonic characteristic of fabricated amplifiers (a) the conventional amplifier and (b) the proposed amplifier.

VI. Conclusion

In this paper, new harmonic termination impedance tuner using asymmetric DGS microstrip and harmonic blocking λ/4 bias line are presented. These circuits suppress harmonic components without affecting electrical characteristics in the operating frequency band. By applying these circuits in amplifier design, harmonic load-pull amplifier design can be easily designed. Since the fabricated harmonic termination impedance tuner that is made with microstrip line has entirely large size and high insertion loss, the proposed amplifier has less P_{1dB} as compared with conventional amplifier. If it can be fabricated with low loss transmission line, it would be possible that an applicable load-pull system is fabricated. It is expected that this impedance tuner and bias line can be used in other microwave circuits.

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