Amplifier Design using λ/4 High Impedance Bias Line with Defect Ground Structure (DGS)

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***Abstract* — In this paper, a new λ/4 bias transmission line that is added dumbbell-shaped defect ground structure (DGS) on ground plane of the conventional λ/4 bias transmission line is proposed. This DGS λ/4 bias transmission line maintains high impedance, but physical width is wider and length is shorter than that of the conventional bias line. If the proposed bias line is attached on signal transmission line, this bias line can reduces the 3rd harmonic signal as well as the 2nd harmonic signal. When the proposed bias line is adopted in power amplifier on IMT-2000 basestation transmitting band, the 3rd harmonic signal is reduced about 26.5dB than the conventional structure.**

I. Introduction

Recently extensive research on photonic band gap (PBG) structure that periodic pattern is etched on ground plane of microstrip line have been conducted for microwave frequency band circuit applications [1]. High efficiency amplifier, filter, and mixer design using PBG are reported [2]-[4]. And defect ground structure (DGS) that one or more dumbbell-shaped ground pattern instead of complex periodic ground pattern is etched on ground plane of microstrip line have been also researched [5]. Directional coupler, filter and power amplifier design using DGS structure are reported [6]-[8]. If PBG and DGS structure that some patterns are etched ground plane of microstrip line can be used effectively, maybe there are many merits on microwave band circuit design.

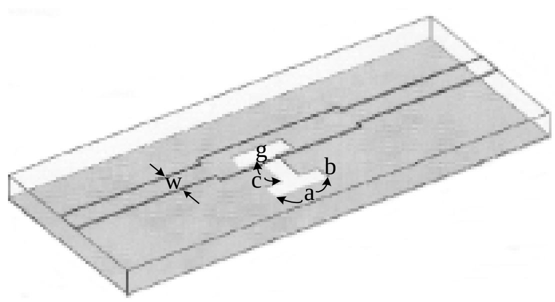
Microwave amplifier is a device to amplify signal on microwave band. Which uses DC bias power as signal amplifying energy and isolation between bias circuit and signal path is very important. Small signal amplifier in UHF band usually uses chip inductor as RF choke in signal transmission line. And also λ/4 transmission line that is terminated with chip capacitor or radial stub is used as bias line. To minimize interference of bias transmission line at signal transmission line, it is good choice that the difference of characteristic impedance between bias transmission line and signal transmission line makes as high as possible. So high impedance λ/4-bias transmission line is generally used. But in case of high power amplifier, transistor consumes much current, so the width of λ/4-bias transmission line is much wider than that of small signal transistor to minimize voltage drop in bias line. That means to reduce characteristic impedance value. So isolation between bias circuit and signal path in high power amplifier is difficult than small signal amplifier and there is much more possibility to oscillate. And when capacitive-terminated λ/4 bias transmission line is connected at signal path, even harmonic frequency components of 1/λ in signal path are blocked but odd harmonic frequency components of 1/λ pass away.

In this paper, we propose a new DGS-type λ/4 bias transmission line that dumbbell-shaped ground plane of microstrip line is etched. This bias line maintains high characteristic impedance value, but width is much wider and length is shorter slightly than the conventional microstrip λ/4 bias transmission line. When the proposed bias line is used in amplifier design, the 3rd harmonic signal as well as the 2nd harmonic signal on signal path can be reduced.

II. λ/4 High Impedance Bias Transimission Line Design using Defect Ground Structure (DGS)

Slight etching of ground plane that located just below microstrip line is equivalent to increasing of serial inductance of transmission line impedance. For defect ground microstrip line maintains the specific characteristic impedance of the conventional microstrip line, width of microstrip line must be wider. That is equivalent to increasing of shunt capacitance of transmission line impedance. Increasing of the equivalent series inductance and shunt capacitance induces increasing of phase constant and slow-wave effect. So defect ground structure of transmission line can make circuit downsizing. Figure 1 show layout of DGS transmission line that is connected 50Ω microstrip line, simulation results of transfer characteristics and slow-wave factor. Where characteristic impedance of DGS transmission line is also 50Ω under 3.5GHz. This circuit is analyzed with Ansoft HFSS V. 6.0.

The used PCB is RT/duroid 5880-of Rogers with dielectric constant (ε_r) of 2.2, and height (h) of 31mil, and copper thickness (t) of 1Oz. And cell parameters of DGS pattern are a=6mm, b=1mm, and g=0.5mm. Width of DGS transmission line (c) is 4.76mm that is much wider than width of the conventional 50Ω microstrip line (w=2.38 mm). The simulated result shows that there is no problem in signal transmission and slow-wave effect is perceptible as frequency increases.



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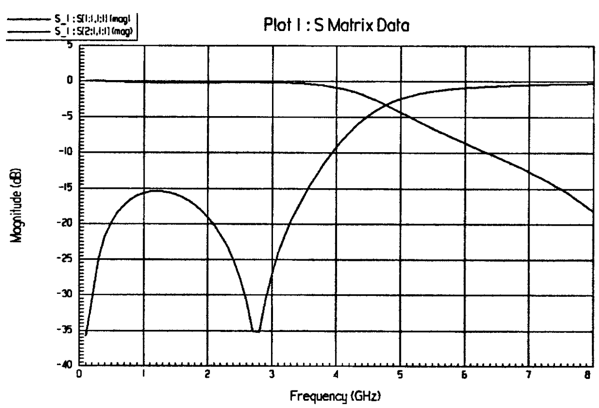

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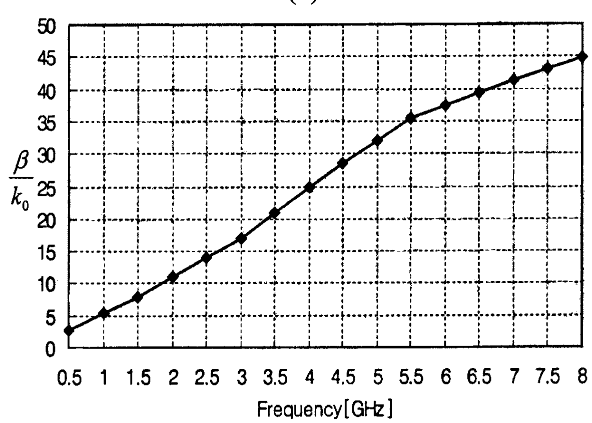


(c)

Fig. 1 (a) Schematic of DGS transmission line
(b) S_{21}, S_{11} characteristics
(c) Slow-wave factor

Slow-wave effect of DGS transmission line according to operating frequency can be adopted to capacitive-terminated λ/4 bias transmission line of power amplifier. If DGS λ/4 bias transmission line can support high impedance value, wider width, and shorter length than conventional bias line and reject the 2nd and 3rd harmonic signals, power amplifier would be more stable and efficient. Figure 2 shows layout of DGS λ/4 bias transmission line connected on 50Ω signal transmission line. Where cell parameters of DGS pattern are a=6mm, b=3mm, g=0.5mm, width of DGS transmission line (c) is 1.23mm. The characteristic impedance of DGS λ/4 bias transmission line is 120Ω and λ/4 length at operating frequency 2.14GHz is 23.8mm. But in case of the conventional λ/4

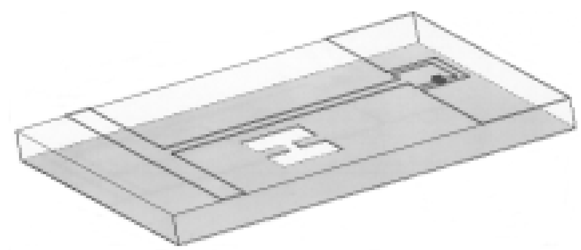
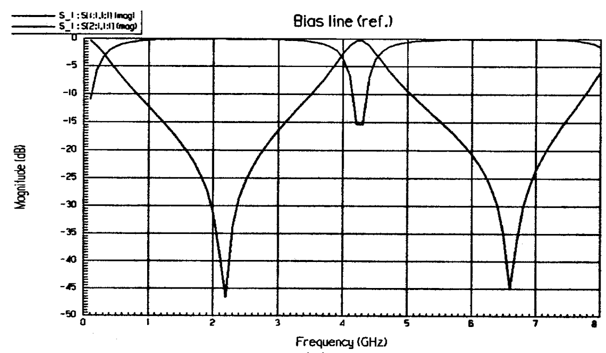


Fig. 2 Layout of DGS λ/4 bias transmission line



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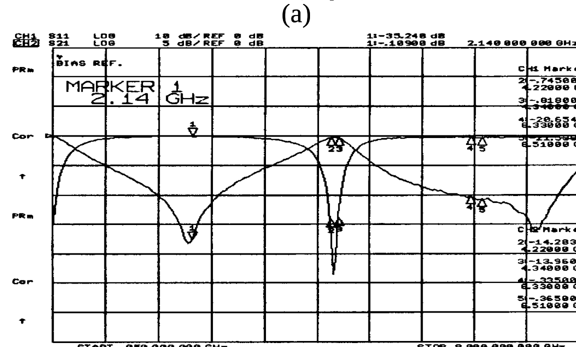

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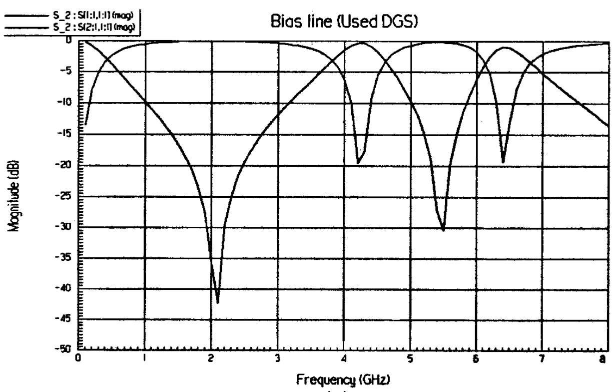
Fig. 3 (a) Simulation result of the conventional λ/4 bias transmission line
(b) Test result of the conventional λ/4 bias transmission line

bias line, width is 0.41mm and length is 25.1mm. So width is enlarged 3 times and length is shorter slightly. Figure 3 shows the simulated and test results of the conventional λ/4 bias transmission line that is connected signal transmission line. Also Figure 4 shows the simulated and test results of DGS λ/4 bias transmission line. The simulated and test results show similar characteristics on the dominant frequency and the 2nd harmonic frequency. But the 3rd harmonic frequency characteristic is different. Whereas the 3rd harmonic frequency component of conventional λ/4 bias transmission line pass away, the 3rd harmonic frequency component of DGS λ/4 bias transmission line can't pass away.



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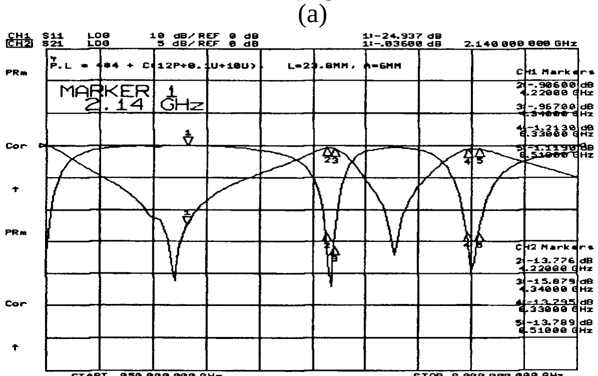


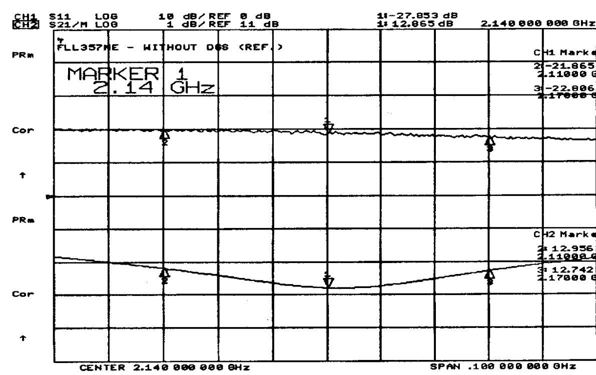
(b)

Fig. 4 (a) Simulation result of DGS λ/4 bias transmission line
(b) Test result of DGS λ/4 bias transmission line

III. AMPLIFIER DESIGN AND TEST RESULTS

To show validation of DGS λ/4 bias transmission line, power amplifier that can be operated in IMT-2000 basestation transmitter is fabricated. Operating frequency is 2.11~2.17GHz and the used transistor is FLL357ME of Fujitsu. When the conventional λ/4 bias transmission line is adopted, gain of fabricated amplifier is 12.8±0.1dB and return loss is less than –21.8dB and 1dB compression point (P_{1dB}) is 35.33dBm. Figure 5 shows transfer and reflective characteristics. And also shows frequency spectrum at 35dBm, that input signal is CW signal. Harmonic characteristics show that the signal difference between the dominant and the 2nd harmonic is 39.21dBc and between the dominant and the 3rd harmonic is 29.55dBc.

Figure 6 shows transfer and reflective characteristics of DGS λ/4 bias transmission line. And also shows frequency spectrum at 35dBm. The gain of fabricated amplifier is 13.35±0.07dB and return loss is less than –21.2dB and 1dB compression point (P_{1dB}) is 35.78dBm. The transfer and reflective characteristics are very similar those of the conventional bias line. Harmonic characteristics show that the signal difference between the dominant and the 2nd harmonic is 40.07dBc and between the dominant and the 3rd harmonic is 56.06dBc. By comparing the amplifier using the conventional λ/4 bias transmission line with the amplifier using DGS λ/4 bias transmission line, the 3rd harmonic signal level can be reduced about 26.51dB. Figure 7 shows photographs of the fabricated amplifier with DGS λ/4 bias transmission line.



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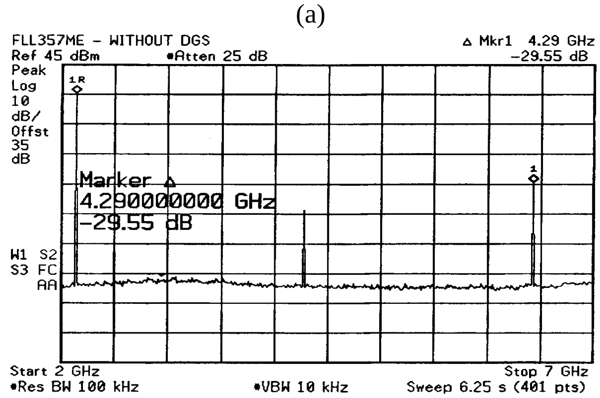

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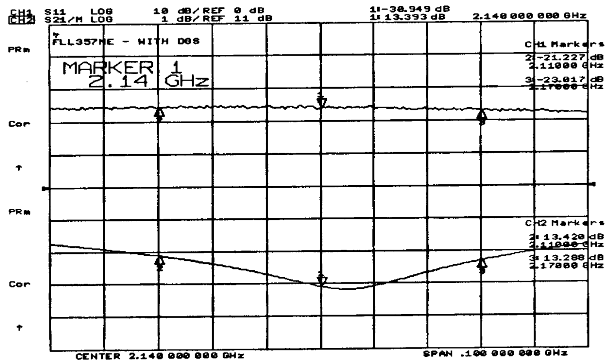
Fig. 5 The fabricated amplifier characteristics using the conventional λ/4 bias transmission line
(a) S_{21}, S_{11}
(b) Harmonic characteristics (@Po=35dBm)



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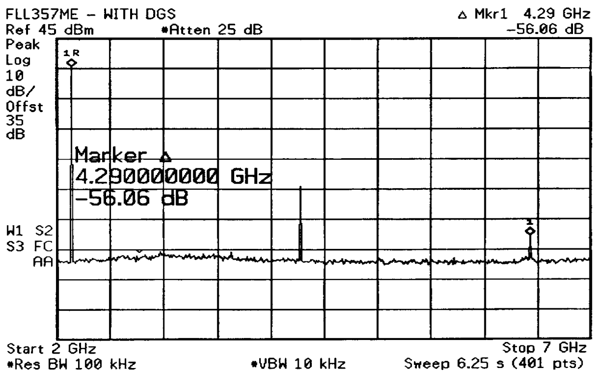

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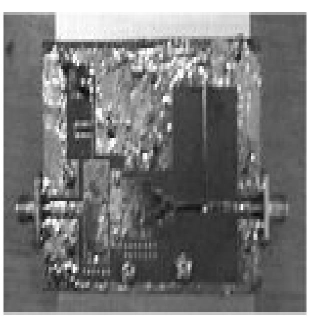
Fig. 6 The fabricated amplifier characteristics using the DGS λ/4 bias transmission line
(a) S_{21}, S_{11}
(b) Harmonic characteristics (@Po=35dBm)



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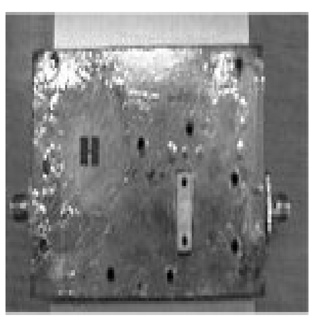

(b)

Fig. 7 Photographs of the fabricated amplifier with DGS λ/4 bias transmission line
(a) Top view
(b) Bottom view

IV. Conclusion

In this paper, we propose a new DGS-type λ/4 bias transmission line that the dumbbell-shaped ground plane of microstrip line is etched. This DGS λ/4 bias transmission line maintains high impedance and offers wider width and shorter length. Also offers signal rejection characteristic of the 3rd harmonic signal as well as 2nd harmonic signal. When this DGS λ/4 bias transmission line is adopted in power amplifier that can be operated in IMT-2000 basestation transmitter, transfer characteristics are similar those of the conventional λ/4 bias transmission line in operating band and the 2nd harmonic band. But the 3rd harmonics signal reduced about 26.5dB than the conventional power amplifier. We think that this bias line can be used other microwave circuit applications.

References

[1] F. R. Yang, Y. Qian, R. Coccioli, T. Itoh, "A Novel Low-Loss Slow Wave Microstrip Structure," *IEEE Microwave and Guided Wave Letters*, Vol. 8, No. 11, pp.372-374, Nov. 1998.

[2] C. Y. Hang, V. Radisic, Y. Qian, T. Itoh, "High Efficiency Power Amplifier with Novel PBG Ground plane for Harmonic Tuning," *IEEE MTT-S Digest*, pp.807-810, 1999.

[3] F. R. Yang, Y. Qian, T. Itoh, "A Novel Uniplanar Compact PBG Structure for Filter and Mixer Application," *IEEE MTT-S Digest*, pp.919-922, 1999.

[4] F. R. Yang, K. P. Ma, Y. Qian, T. Itoh, "A Uniplanar Compact Photonic-Bandgap (UC-PBG) Structure and Its Applications for Microwave Circuits," *IEEE Transactions on Microwave Theory and Techniques*, Vol.47, No. 8, pp.131-133, Apr. 2000.

[5] C. S. Kim, J. S. Park, D. Ahn, J. B. Lim, "A Novel 1-D Periodic Defected Ground Structure for Planar Circuits," *IEEE Microwave and Guided Wave Letters*, Vol. 10, No. 4, pp.131-133, Apr. 2000.

[6] C. S. Kim, J. S. Lim, J. S. Park, D. Ahn, S. W. Nam, "A 10dB Branch Line Coupler Using Defected Ground Structure," *European Microwave Conference Digest*, pp.68-71, 2000.

[7] J. S. Yun, G. Y. Kim, J. S. Park, D. Ahn, K. Y. Kang, J. B. Lim, "A Design of the Novel Coupled Line Bandpass Filter Using Defected Ground Structure," *IEEE MTT-S Digest*, pp.327-330, 2000.

[8] J. S. Lim, H. S. Kim, J. S. Park, D. Ahn, S. W. Nam, "A Power Amplifier with Efficiency Improved Using Defected Ground Structure," *IEEE Microwave and Wireless Components Letters*, Vol. 11, No. 4, pp.170-172, Apr. 2001.