Spurious Emission from Microstrip Oscillator Circuit

Han-Chang Hsieh[1], Jay-San Chen[2], Chi-Hsueh Wang[1], Cheng-Nan Chiu[3], Ming-Shing Lin[4], and Chun Hsiung Chen[1],

[1]*Department of Electrical Engineering and Graduate Institute of Communication Engineering, National Taiwan University, Taipei 106, Taiwan.*

[2]*Bureau of Standards, Metrology and Inspection (BSMI), Ministry of Economic Affairs, Taiwan.*

[3]*Department of Electrical Engineering, Da-Yeh University, Changhua 515, Taiwan.*

[4]*Department of Electrical Engineering, National Yunlin University of Science and Technology, Yunlin 640, Taiwan.*

[1]d95942001@ntu.edu.tw , [1]f86942008@ntu.edu.tw, [1]chchen@ew.ee.ntu.edu.tw
[2]Js.chen@bsmi.gov.tw , [3]cnchiu@mail.dyu.edu.tw, [4]starlin@yuntech.edu.tw

***Abstract*—The previously developed fast model is adopted to characterize the electric field radiated from a microstrip oscillator circuit. The oscillator circuit is nonlinear and autonomous, and may cause a large amount of spurious emission. In this paper, both simulated and measured results are presented and good agreement between them is observed. By using the field-expressions-incorporated circuit solver, the adopted fast model would be very useful and efficient in predicting the field radiated from the whole oscillator circuit.**

Index terms—Spurious emission, microstrip oscillator.

I. INTRODUCTION

The requirement of RF and microwave circuits for wireless broadband applications has been rapidly increased during the last few years. To be successful in the wireless market, the design of the RF and microwave circuits need to be compact in size, low cost, and low power consumption. With the advances in the state-of-the-art design tools (such as the circuit solvers), they have now reached a stage for efficiently characterizing RF and microwave circuits with active components. Specifically, the circuit solvers have become a good candidate for handling RF and microwave circuits with broadband applications.

RF and microwave microstrip oscillators are the key components in the modern wireless communication systems. Recently, many structures have been developed to implement the microstrip oscillators [1]-[3]. The electromagnetic interference (EMI) from the oscillator circuit becomes more and more serious as the frequency increases. Till now, some techniques have been proposed to reduce the EMI from the oscillator, such as using a shielding box, skew-rate control, and so on [4], [5]. However, only very few work was reported to estimate the spurious emission directly from the oscillators.

In this paper, the fast model developed in [6] is adopted to predict the electric field radiated from the microstrip oscillator circuit. This model, using the field-expressions-incorporated circuit solver, has been proved to be efficient in predicting spurious emissions from complicated circuit configurations on PCB, certainly including the oscillator circuit as considered here.

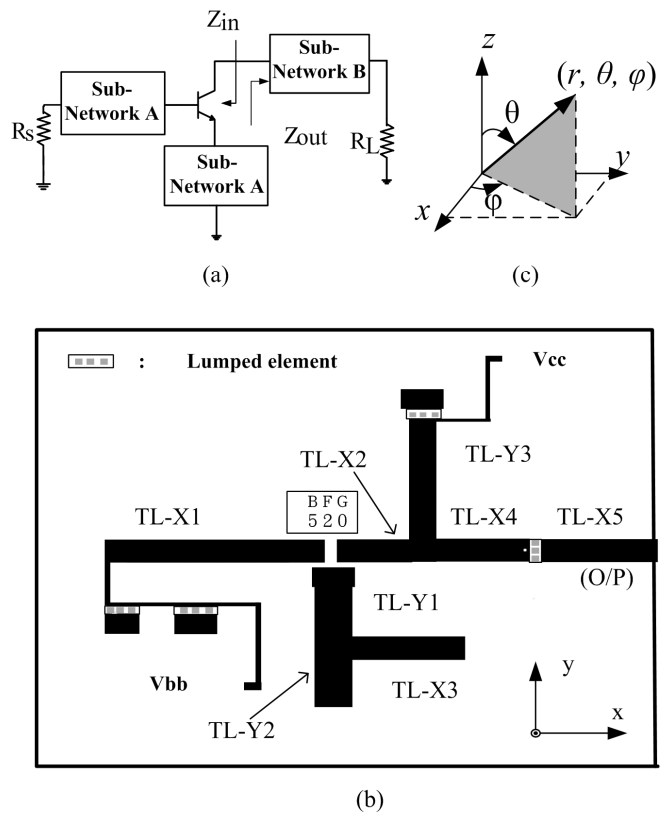

Fig 1. Microstrip oscillator circuit, (a) schematic diagram, (b) layout with transistor (BFG520) and lumped elements removed, (c) coordinate system associated with the oscillator.

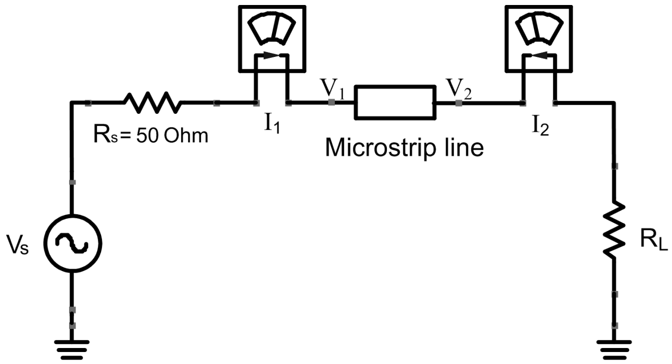

Fig. 2. Circuit diagram for extracting the port voltages and currents, (V_1, I_1), (V_2, I_2).

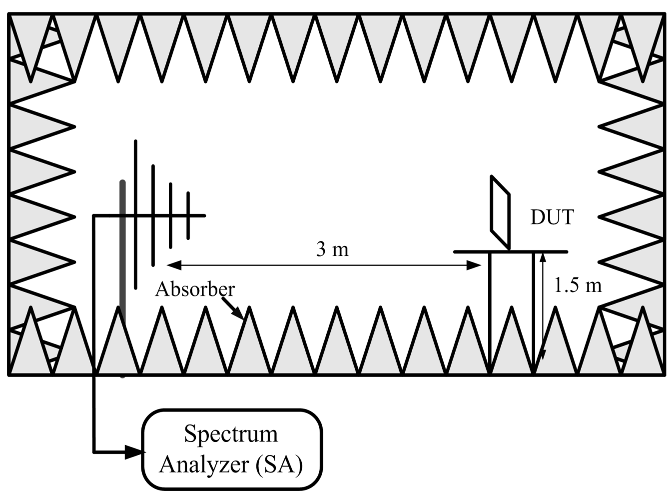

Fig. 3. Setup for measuring the spurious emission from the oscillator circuit.

II. Microstrip Oscillator Circuit

In this paper, the microstrip oscillator with explicit structure shown in Fig. 1(a) is dealt with. It consists of a discrete BJT transistor (such as BFG 520 with nonlinear BJT model [7]), the matching microstrip network (sub-network A), and the output matching microstrip network (sub-network B). The transistor network impedance $\boldsymbol{Z_{in}}$ is characterized by possessing a one-port negative-resistance, and $\boldsymbol{Z_{out}}$ is the load network impedance. Following the design procedure [8], the microstrip oscillator circuit can be established on the ADS circuit solver platform [9].

The transistor network impedance $\boldsymbol{Z_{in}}$ at the collector is then tuned to achieve a negative impedance around 780-820 MHz. The output matching microstrip network is designed to give an optimal negative resistance at 800 MHz, so that maximum output power may be extracted from the transistor.

TABLE I. Geometric parameters for microstrip line elements in Fig. 1(b).

Element	Width (mm)	Starting point (mm)	Terminated point (mm)
TL-X1	1.42	(0, 0)	(34.2, 0)
TL-X2	1.42	(37.2., 0)	(52.3, 0)
TL-X3	1.42	(35.7, 0)	(68.4, 0)
TL-X4	1.42	(54.7, 0)	(76.5, 0)
TL-X5	1.42	(77.5, 0)	(82.5, 0)
TL-Y1	1.42	(35.7,0)	(35.7, -30.3)
TL-Y2	1.42	(35.7, -31.4)	(35.7, -47.4)
TL-Y3	1.42	(54, 0)	(54, 27.8)

The configuration of microstrip oscillator circuit on PCB is shown in Fig. 1(b) with parameters given in Table 1. The spherical coordinates ($\boldsymbol{r}$, θ, ϕ) associated with the oscillator is depicted in Fig. 1 (c).

III. Spurious Emission

Basically, the microstrip oscillator circuit shown in Fig. 1 is mainly consisting of lumped elements, microstrip bends, microstrip line traces, and active components. Since the electric fields radiated from the microstrip traces are larger than those from the other elements (chipset resistors, capacitors, bends, and active transistor), the microstrip oscillator circuit can simply be regarded as a cascade of several microstrip lines when the EMI topic is of main concern. In this study, the fast simulation model developed in [6] is adopted to treat the spurious emission problem associated with the complicated RF microstrip oscillator circuit which contains several microstrip elements.

It is a straightforward process to predict the radiated fields from the port voltages and currents extracted from the ADS circuit solver, merely following the simulation steps summarized in [6].

For instance, to handle the single microstrip trace, one may simply obtain the port voltages and currents by connecting a voltage source, two current probes, and a suitable load to the corresponding ports of a microstrip line on the commercial circuit solver platform as shown in Fig. 2. Consequently, once the port voltages and currents, (V_1, I_1), (V_2, I_2), associated with the microstrip trace have been extracted from the circuit solver, the radiated electric field from the single microstrip line may easily be calculated by the field-expressions-incorporated circuit solver.

Specifically, the port voltages and currents (V_i, I_i) at (x_i, y_i), associated with each microstrip element, should be

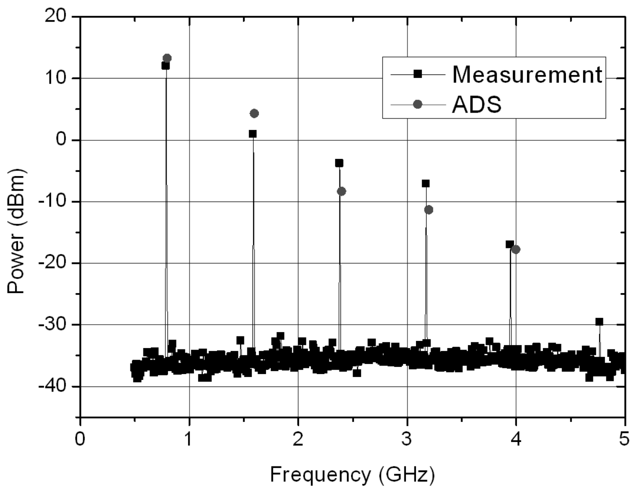

Fig. 4. Output power of the microstrip oscillator circuit on PCB (Fig. 1).

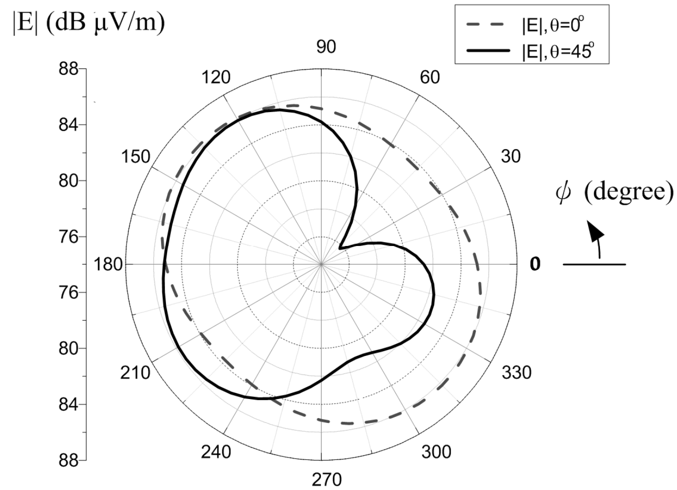

Fig. 6. Directional responses of electric fields radiated from the microstrip oscillator (Fig. 1). The fields are observed at r=3 m, θ=0 °, 45 °, and ϕ =0 ~ 360°.

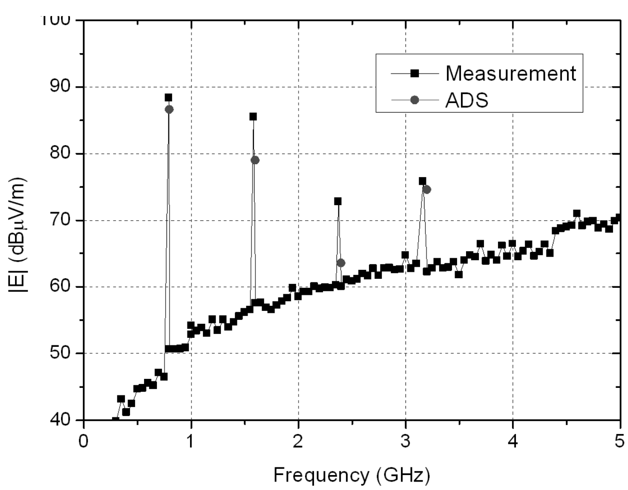

Fig. 5. Measured and simulated fields radiated from the microstrip oscillator (Fig. 1), observed at ***r***=3 m and $\theta = \phi = 0$ °.

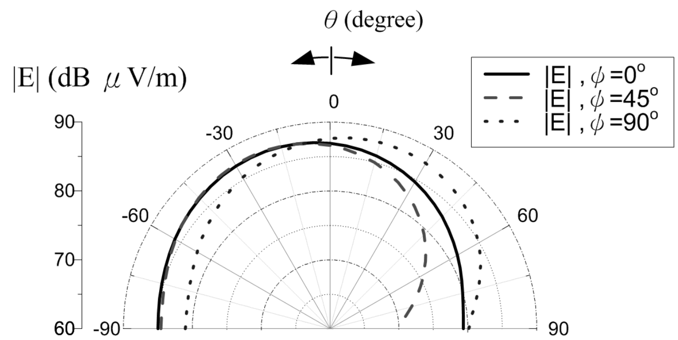

Fig. 7. Directional responses of electric fields radiated from the microstrip oscillator (Fig. 1). The fields are observed at r=3 m, ϕ =0 °, 45°, 90°, and θ= -90 ° ~ 90°.

extracted in advance, by using the circuit solver. Then, the extracted port quantities (V_i , I_i) are substituted into the analytical field expressions in [6] which have been incorporated into the circuit solver. The total radiated electric field from this specific oscillator circuit configuration may finally be determined by combining the contributions from all elements on the same circuit solver. By incorporating the analytical field expressions into the circuit solver, the adopted fast model would be very efficient in discussing the spurious emission problem associated with the microstrip oscillator circuit.

For validation, the output port of the microstrip oscillator circuit is connected to a load Z_L=50 Ω. This oscillator circuit is implemented on PCB with FR4 substrate (ε_r=4.6, h= 1.6 mm), and the geometric parameters for each microstrip line element is given in Table 1. Finally, the dc power supply voltages for the oscillator are provided by the 3-V and 0.8-V dc voltages V_{CC} and V_{BB} from battery sources, respectively.

The spurious emission from the oscillator is received by the R&S FSP spectrum analyzer equipped with the wide-band antennas (Emco 3115 and Schwarzbeck UHALP 9107). The radiated field is received by the broadband antenna within the anechoic chamber, which is located at the *Bureau of Standard, Metrology and Inspection* (*BSMI*) of Taiwan. The cases for both vertical and horizontal polarizations are measured. The distance between antenna and the DUT is 3.0 m. The setup for

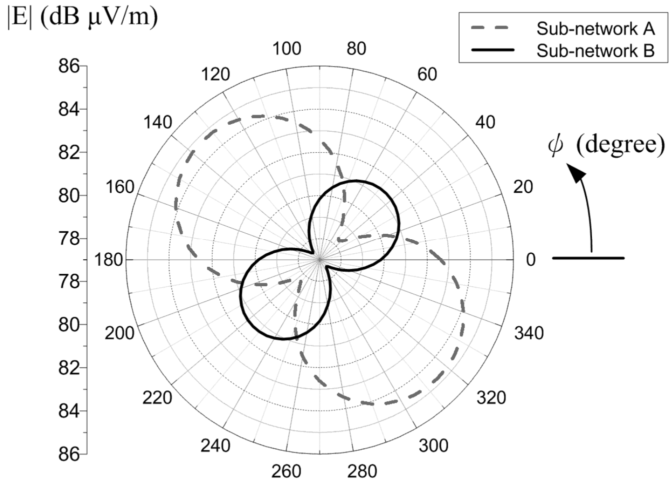

Fig. 8. Electric fields radiated from microstrip sub-network A and sub-network B, observed at r=3 m and $\theta = 0^{o}$.

measuring the spurious emission from the oscillator circuit is shown in Fig. 3.

The oscillation power associated with this oscillator circuit is depicted in Fig. 4. A good agreement between simulated and measured results is observed as shown in Fig. 4. Fig. 5 shows the radiated electric field at the observation point ***r*** = 3 m, $\theta = \phi = 0^{\circ}$. Note that the radiated electric fields are also observed for the harmonics of the microstrip oscillator.

Here, the electric fields radiated from the microstrip oscillator in the observation range r=3 m, $\theta = 0^{o}$, 45^{o}, and $\phi = 0 \sim 360^{o}$ are also plotted in Fig. 6. Data in Fig. 6 are obtained for the microstrip circuit operating at fundamental frequency. These results indicate that the minimum radiated electric field is observed at the angle $\theta = 45^{o}$, $\phi = 90°$. The directional responses of electric fields radiated from the oscillator in the observation range r=3 m, $\phi = 0^{o}$, 45^{o}, 90^{o}, and $\theta = -90^{o} \sim 90^{o}$ are also plotted in Fig. 7. Obviously, maximum radiations are observed at ($\phi = 0^{o}$, 45^{o}, and $\theta = -30^{o}$) and ($\phi = 90^{o}$, and $\theta = 30^{o}$).

In designing a microstrip oscillator, it is essential to give a high power output with low spurious emission. Fig. 8 illustrates the electric fields radiated from the microstrip sub-networks (A and B) of the oscillator. For the sub-network A, maximum radiations are located at ($\phi = 120^{o}$ -160^{o}, and 300^{o}-340^{o}), while for the sub-network B, maximum radiations are located at ($\phi = 40^{o}$ and 220^{o}). Obviously, the spurious emission from the microstrip oscillator is mainly contributed from the sub-network A.

IV. CONCLUSION

In this work, the spurious emission from the microstrip oscillator has been investigated through both simulation and measurement. By comparing the responses of electric fields radiated from sub-networks A and B of the oscillator in the observation range r=3 m, $\theta = 0^{o}$, 45^{o}, and $\phi = 0 \sim 360^{o}$, it is found that the major source of spurious emission is from the sub-network A which should be carefully designed for emission reduction. This work demonstrates that the adopted model is an effective and useful design tool in discussing the EMC spurious emission topic even for sensitive autonomous oscillator circuits.

ACKNOWLEDGMENT

This work was supported by the Excellent Research Projects of National Taiwan University, NTU-ERP-98R0062-AE00-00.

REFERENCES

[1] K. Kawahata, N. Miyayoshi, and M. Aikawa, “A novel microwave oscillator using double-sided MIC,” in *IEEE Int. Microw. Symp. Dig.,* June 2002, pp. 699-702.

[2] K. M. Strohm, C. N. Rheinfelder, J. F. Luy, P. Nuechter, T. Hess, W. Heinrich, H. Kuhnert, M. Nadarassin, C. Warns, and W. Menzel, “Coplanar and microstrip oscillators in SiGe SIMMWIC technology,” in *IEEE Int. Microw. Symp. Dig.,* June 2001, pp. 1563-1566.

[3] A. M. Moselhy and M. Fouad, “Optimum microwave oscillator design using small-signal S-Parameters,” *Proceedings of the Thirteenth National Radio Science Conference,* Mar. 19-21, 1996, Cairo, Egypt.

[4] D. Sheng, C. Chung, and C. Y. Lee,” An all digital spread spectrum clock generator with programmable spread ratio for SoC applications,” in *IEEE Int. EMC Symp.,* Aug. 2008, pp. 850-853.

[5] A. M. E. Tager, E. A. Abdallah, and M. A. Nassef, “An improved nonlinear analysis & design method of microstrip oscillators based on modern CAD techniques,” in *IEEE Int. EMC Symp.,* Aug. 1999, pp. 128-131.

[6] H. C. Hsieh, C. N. Chiu, C. H. Wang, and C. H. Chen, “A new approach for fast analysis of spurious emissions from RF/Microwave circuits,” *IEEE Trans. on Electromagn. Compat.,* vol.51, no. 3, pp. 631-638, August 2009.

[7] http://www.nxp.com/models/spicespar/BFG67.html

[8] Guillermo Gonzalez, “*Microwave Transistor Amplifiers Analysis and Design*,” PEARSON, 2008, Taiwan.

[9] http://eesof.tm.agilent.com/