IF-TH-55

A Semi-lumped Balun Fabricated by Low Temperature Co-fired Ceramic*

Ching-Wen Tang and Chi-Yang Chang†

Phycomp Taiwan Ltd., Kaohsiung 811, Taiwan, R.O.C.

†Department of Communication Engineering, National Chiao Tung University

Hsinchu 300, Taiwan, R.O.C.

Abstract **— A new chip-type multi-layer ceramic balun is presented in this paper. This balun is designed in the ISM band and fabricated using low temperature co-fired ceramic (LTCC) technology. It involves the semi-lumped concept and the multi-layer structure to realize the LTCC-MLC balun. The symmetric structure holds the excellent characteristics of phase balance and amplitude balancing. Measured results of the LTCC-MLC balun match well with the computer simulation.**

I. INTRODUCTION

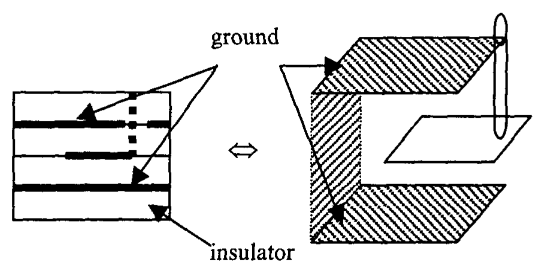
The size reductions of RF components are an important part in the wireless and mobile communication system for the miniaturization and cost reduction. Balun is the key component in realization of balanced mixers, amplifiers, multipliers, and phase shifters. The Marchand balun [1] consists of two coupled-line sections, which may be realized using microstrip coupled-line [2], Lange couplers [3], spiral coil [4], or multi-layer coupled structure [5].

The multi-layer ceramic technology seems to be the best solution to realize chip type elements [6]-[7]. We have published the various even and odd modes coupling coefficient method [8] to shrink the length of transmission-line. There are two types of LTCC processing, namely the shrinkage and non-shrinkage technologies to be adopted in the fabrication of RF components or modules. After sintering [9], the ceramic materials need to burnout the binder and densification that will cause the size of components to shrink. The non-shrinkage technology, which use the alumina sheet to constrain the planar size [10] or the clad metal base to provide constrained sintering [11], can provide another choice, but the process is complicate in the fabrication.

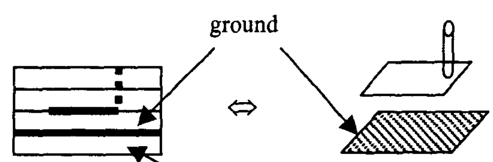
This paper presents the new design method of chip-type balun. It uses the semi-lumped concept and the multi-layer structure to realize the LTCC-MLC balun. This method easily overcomes the effect of size shrinkage due to processing and increase the yield rate of mass production. This balun shows broader bandwidth, better phase balancing, and looser processing control. The calculated and measured results of the fabricated LTCC-MLC balun show excellent performance.

II. DESIGN PROCEDURE

The semi-lumped resonator, which comprises two metal-insulator-metal (MIM) capacitors and a section of transmission-line, shows shorter length than a half-wavelength transmission-line resonator. Fig.1 shows two types of MIM capacitor that can be used in the multi-layer structure.



(a) The MIM capacitor of type I



(b) The MIM capacitor of type II

*Patent pending

Fig. 1. The overview of two types of multi-layer MIM capacitor.

In the processes of fabricating the LTCC circuit, there are two main effects to decide the accuracy of components. Firstly, the method of forming the wiring patterns is using the screen-printing technology [12] that the accuracy is up to the size of mesh. Secondly, the dimension of conventional LTCC substrate has a large distribution after sintering (± 0.5%) [10]. These effects may cause the designed frequency drift. The proposed balun avoids this effect by adopting the semi-lumped method. The shrinkage in length of the transmission lines is the main reason of drifting of frequency. Using the semi lumped design can largely minimize this effect because the inductance increases and capacitance decreases by shrinkage effect. When circuit is shrunken the line width of the inductor becomes thinner, therefore the inductance is increased. However, the capacitance decreases due to area shrinkage. The overall effect is that the LC product keeps unchanged.

Shown in Fig.2 is the equivalent circuit of the proposed LTCC-MLC balun. It comprises of two coupled transmission lines and four lumped capacitors. The concept of size shrinkage is somewhat similar to that of stepped impedance method [13].

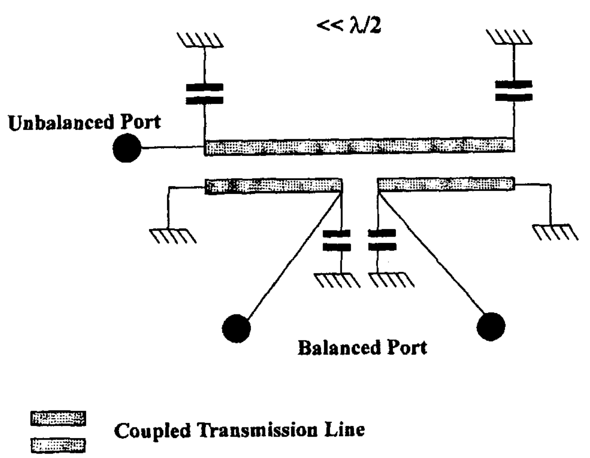


Fig. 2. The equivalent circuit of LTCC-MLC balun.

Fig.3 shows the multi-layer structure of this semi-lumped balun. The lengths of coupled lines are limited by the chip size. By properly control of these MIM capacitors, the coupled lines length can be reduced effectively.

There are three steps to construct the LTCC-MLC balun: meandering the coupled-lines, multi-layer structure, and series connecting to the MIM capacitors. The combination of transmission line and MIM capacitor is very useful in holding the designed frequency band and in reducing the size of this chip-type balun.

Because the structure of this balun is symmetric, it can be separated into two parts and can be folded to upper (or lower) layer. Finally, two coupled center strips can be meandered to shrink the balun further.

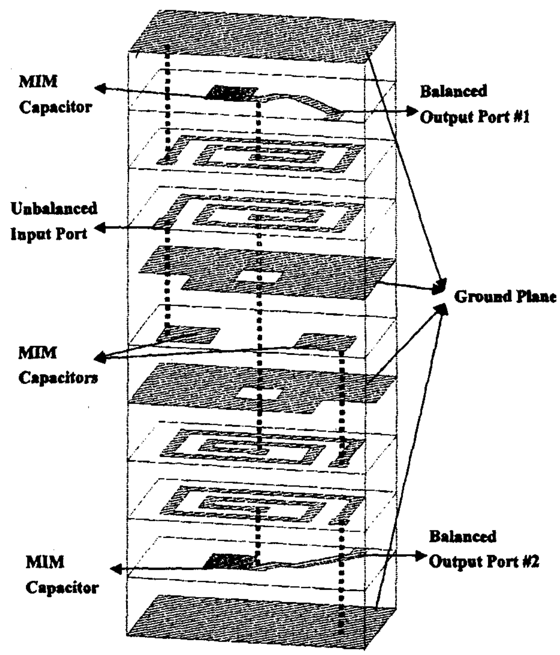


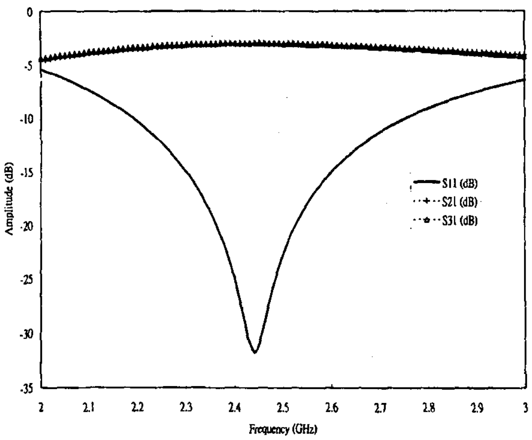
Fig. 3. The multi-layer structure of proposed LTCC-MLC balun.

III. DESIGN AND SIMULATION

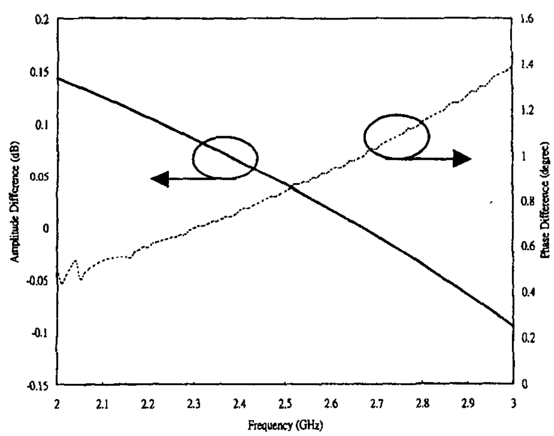
In the realization of chip balun, it comprises two meandered coupled lines in multi-layer structure, four MIM capacitors connected in series with the coupled lines. The chip type balun is designed to operate in the frequency range of 2.25-2.65GHz. Unbalanced input impedance and two balanced output impedances were all 50Ω. The proposed multilayer chip type balun has been investigated using a full-wave electromagnetic (EM) simulator [14].

The simulated results are shown in Fig.3. The insertion loss and the return loss are less than −0.24dB and −12.4dB respectively in the operating frequency band as shown in

Fig.3(a). The amplitude and phase imbalance between balanced output are within 0.1dB and 0.98° respectively over the same frequency band as shown in Fig.3(b).



(a) The simulated insertion loss and return loss



(b) The simulate balanced output amplitude and phase characteristics

Fig. 4. The simulated results of designed chip type balun.

IV. EXPERIMENT RESULT

Fig.5 shows the fabricated LTCC-MLC balun. The designed chip type balun is fabricated with multi-layer configuration using Heraeus CT700 40um-thick ceramic sheets (εr=7.2) and 10um-thick Ag metal pattern. The overall size of the balun is 2.0mm x 1.2mm x 0.8mm.

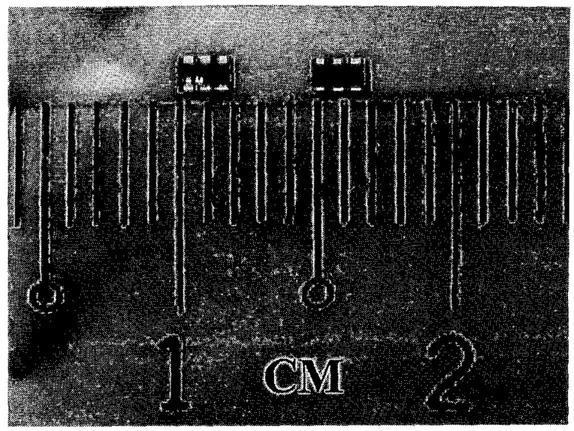
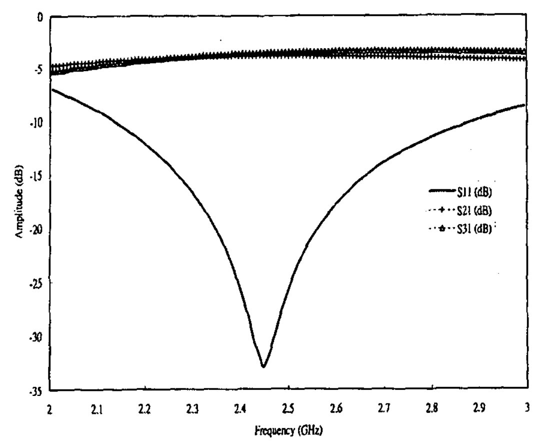
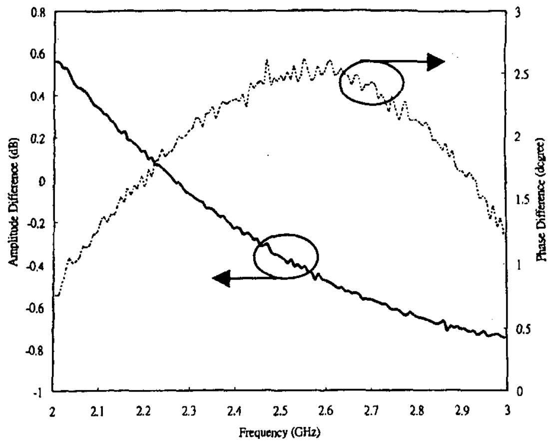


Fig. 5. The fabricated chip type balun.

The measured results are shown in Fig.6. The insertion loss and return loss are less than −1dB and −14dB respectively over the operating frequency band as shown in Fig.6(a). Fig.6(b) shows the measured amplitude and phase difference between balanced output. The amplitude and phase imbalances are within 0.53dB and 2.59° respectively over the operating frequency band.



(a) The measured insertion loss and return loss



(b) The measured amplitude and phase difference

Fig. 6. The measured result of fabricated chip type balun.

V. Conclusion

The novel LTCC-MLC balun has been developed. The design method and the equivalent circuit of this balun have been given. The design procedures are simple. The size of this balun is compact, and measured performance is excellent. This balun has been designed with the operating frequency range of 2.25-2.65GHz. Unbalanced input impedance and two balanced output impedances are 50Ω. The designed chip type balun has been fabricated with multilayer configuration. The insertion loss and return loss are less −1dB and −14dB respectively over the operating frequency band. The measured amplitude and phase imbalances between balanced outputs were within 0.53dB and 2.59° respectively over the operating frequency range. The simulated and measured results show the validity of the proposed design method and the equivalent circuit of the balun.

Acknowledgment

The authors would like to thank the staff in the Phycomp Taiwan Ltd., Kaohsiung, Taiwan, R.O.C., for the manufacture of the MLC balun and the improvement of the LTCC processing. They also appreciate the support given by Dr. W.-S. Lee and C.-L. Hu.

References

[1] N. Marchand, "Transmission line conversion transformers," *Electronics*, vol. 17, No. 12, pp. 142-145, December 1942.

[2] R. Schwindt and C. Nguyen, "A CAD procedure for the double-layer broadside-coupled Marchand balun," *1994 IEEE MTT-S Int. Dig.*, pp. 389-391, 1994.

[3] J. Rogers and R. Bhatia, "A 6 to 20 GHz planar balun using a Wilkinson divider and Lange couplers," *1991 IEEE MTT-S Int. Dig.*, pp. 865-868, 1991.

[4] K. S. Ang, S. B. Economides, S. Nam and I. D. Robertson, "A compact MMIC balun using spiral transformers," *1999 IEEE MTT-S Int. Dig.*, pp. 655-658, 1999.

[5] Y. Fujiki, H. Mandai and T. Morikawa, "Chip type spiral broadside coupled directional couplers and baluns using low temperature co-fired ceramic," *1999 IEEE Electronic Components and Technology Conference*, pp. 105-110, 1999.

[6] T. Ishizaki and T. Uwano, "A stepped impedance comb-line filter fabricated by using ceramic lamination technique," *1994 IEEE MTT-S Int. Dig., WEIC-4*, pp. 617-620, 1994.

[7] T. Ishizaki, H. Miyake, T. Yamada, H. Kagata, Hiroshi Kushitani and K. Ogawa, "A first practical model of very small and low insertion loss laminated duplexer using LTCC suitable for W-CDMA portable telephones," *2000 IEEE MTT-S Int. Dig.*, pp. 187-190, 2000.

[8] C. W. Tang, J. W. Sheen and C. Y. Chang, "Chip-type LTCC-MLC baluns using stepped impedance method," *IEEE Trans. Microwave Theory Tech.*, vol. 49, no. 12, pp. 2342-2349, December 2001.

[9] Z. Han, J. Ma, Z. Xu, Q. Wang, L. Huang and Y. Li, "Sintering processing of low temperature cofired ceramics," *2000 Int'l Symp on Electronic Materials and Package*, pp. 436-439, 2000.

[10] M. Itagaki, Y. Bessho, K. Eda and T. Ishida, "A zero X-Y shrinkage low temperature cofired ceramic substrate using Ag and AgPd conductors for flip-chip bonding," *1996 IEEE/CPMT Int'l Electronics Manufacturing Technology Symposium*, pp. 156-161, 1996.

[11] A. Fathy, V. Pendrick, G. Ayers, B. Geller, Y. Narayan, B. Thaler, H. D. Chen, M. J. Liberatore, J. Prokop, K. L. Choi, M. Swaminathan, "Design of embedded passive components in Low-Temperature Cofired Ceramic on Metal (LTCC-M) technology," *1998 IEEE MTT-S Int. Dig.*, pp. 1281-1284, 1998.

[12] J. C. Bolger and J. M. Czarnowski, "Area bonding conductive epoxy adhesives for low-cost grid array chip carriers," *IEEE Transactions on Components, Packaging, and Manufacturing Technology, Part C*, vol. 19, no. 3, pp. 184-188, July 1996.

[13] M. Makimoto and S. Yamashita, "Compact bandpass filter using stepped impedance resonators," *Proc. IEEE*, vol. 67, pp. 16-19, January 1979.

[14] ***em user's manual,*** Sonnet Software Inc., Liverpool, NY.