

Microwave Applications of Left/Right-handed Transmission Lines

I. Vendik¹, O. Vendik¹, D. Kholodnyak¹, S. Zubko¹, I. Kolmakov¹
 I. Kolmakova¹, E. Serebryakova¹, I. Nefedov², S. Tretyakov²
 F. Martín³, J. Bonache³, J. García-García³, and I. Gil³

¹St.-Petersburg Electrotechnical University, Russia

²Helsinki University of Technology, Finland

³Universitat Autònoma de Barcelona, Spain

Numerous investigations have been undertaken in the area of metamaterials exhibiting negative refractive index. Such artificial materials are also known as Veselago media or left-handed materials. Recently a transmission line (TL) approach to realization of metamaterials was introduced [1–3]. Concept of right-handed (RH) and its dual left-handed (LH) transmission lines was used for a description of artificial transmission lines. In this review paper we will present some recent developments in this field.

A possibility to design a phase shifter with reduced frequency dispersion using combined sections of LH TL and RH TL was analyzed [4]. It was shown that there is no improvement in the phase shifter bandwidth due to combining positive and negative transmission line sections, except replacing devices with large positive phase shifts by devices with an equivalent small negative phase shift. Reduction of frequency dispersion can be attained using artificial transmission-line sections with positive anomalous dispersion.

An attractive feature of LH and RH lines is that the dispersion characteristics of both lines have a negative-going slope and the frequency dependencies of the slope for these lines are in a close agreement over a wide frequency range. That makes possible a design of a wide-band digital phase shifter based on switchable LH and RH TL channels. A theoretical approach was suggested and applied to i) digital phase shifters based on switchable LH and RH TL channels using p-i-n diodes and ii) digital phase shifters based on tuneable composite RLH-TL using ferroelectric varactors [5]. Results of simulation and experimental investigations of one-bit and multi-bit phase shifters are presented.

Another interesting application of CRLH-TL concerns microwave filters. Specifically, by alternating LH and RH TL sections implemented by means of split rings resonators (SRR) or complementary split rings resonators (CSRR), it is possible to synthesise narrow band pass filters [6] and duplexers [7] with high frequency selectivity and small dimensions. This is achieved thanks to the resonant nature of the artificial TL sections employed, to the small electrical size of the resonators, and to the presence of transmission zeros, which can be tailored to achieve the required characteristics.

REFERENCES

1. Eleftheriades, G. V., O. Siddiqui, and A. K. Iyer, *IEEE Microwave and Wireless Component Letters*, Vol. 13, 51–53, 2003.
2. Caloz, C. and T. Itoh, *IMS 2003 Digest*, 195–198, 2003.
3. Antoniadis, M. A. and G. V. Eleftheriades, *IEEE Antennas and Wireless Propagation Letters*, Vol. 2, 103–106, 2003.
4. Nefedov, I. S. and S. A. Tretyakov, *Microwave and Optical Technology Letters*, Vol. 45, 98–102, 2005.
5. Vendik, O. G., I. B. Vendik, D. V. Kholodnyak, S. P. Zubko, and E. V. Serebryakova, *Proc. EuMC35*, 909–912, Paris, 2005.
6. Bonache, J., F. Martín, F. Falcone, J. García-García, I. Gil, T. Lopetegui, M. A. G. Laso, R. Marqués, F. Medina, and M. Sorolla, *Microwave Opt. Technology Letters*, Vol. 46, 33–35, July 2005.
7. Bonache, J., I. Gil, J. García-García, and F. Martín, *Electronics Letters*, Vol. 41, 810–811, July 2005.