Tunable Differential Phase Shifters Using MEMS Positive/Negative Phase Velocity Transmission Lines

Julien Perruisseau-Carrier and Anja K. Skrivervik
Laboratory of Electromagnetics and Acoustic (LEMA),
Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland.

In this work, we present new designs of reconfigurable phase shifters for *ku* band based on MEMS devices. The principle of the phase shifters is shown in Fig. 1 and relies on the particular dispersion properties of artificial transmission lines (TL) with positive/negative phase velocity, referred to here as variable composite right/left handed TL (V-CRLHs). Using this topology and V-CRLHs allows achieving versatile differential phase shift functions ϕ by adjusting the length and dispersion of each line section.

In particular, we will demonstrate here two types of devices. In the first case, the phase shifter is designed to obtain ϕ *constant* in frequency on a wide bandwidth (BW) and this device is thus referred to as the MEMS *constant*-phase shifter (M-CPS). This application is the reconfigurable counterpart of the structure presented in (M. Lapine and al., 36th European Microw. Conf., Manchester, UK, pp. 427-430), where we added a usual right-hand TL section in one of the branch to compensate for the difference between the slopes of the dispersion curves of each V-CRLH, as explained by the diagram of Fig. 1. Each V-CRLH section in Fig. 1 is first implemented by analog MEMS V-CRLH as presented by the authors in (J. Perruisseau-C. and al., MOTL, 48, 12, pp. 2496-2499). Since each element in the structure is well matched, the differential phase shift is simply $\phi = \phi_B - \phi_A = \phi_B - \phi_{A,0} - \phi_{RH}$. This quantity is plotted in Fig. 2 on a 5% fractional BW in the passband of the CRLHs. The two curves in solid lines correspond to the maximum and minimum differential phase shifts and the 3 curves in dashed lines represent intermediate states within this analog range. The range obtained is 55^o at the center of the BW and the maximum phase error is less than 3.5^o (resp. 9^o) on a on 5% BW (resp. 10% BW). Nevertheless, it can be shown that this range can be significantly extended by using *digital* MEMS V-CRLHs, whose measured results will be presented at the conference.

In a second stage, we show that the topology of Fig. 1 also allows realizing devices providing a tunable differential *group delay* which is constant in frequency on a significant BW. The difference with the M-CPS described above is simply that the two branches must be designed so that the phase difference is linear (rather than constant) with frequency. A comparison with distributed MEMS transmission lines on the same technology (J. Perruisseau-C. and al., IEEE T-MTT, 54, 1, pp. 383-392) showed that such structure is advantageous for some applications in terms of delay/losses and footprint, at the cost of reduced BW.

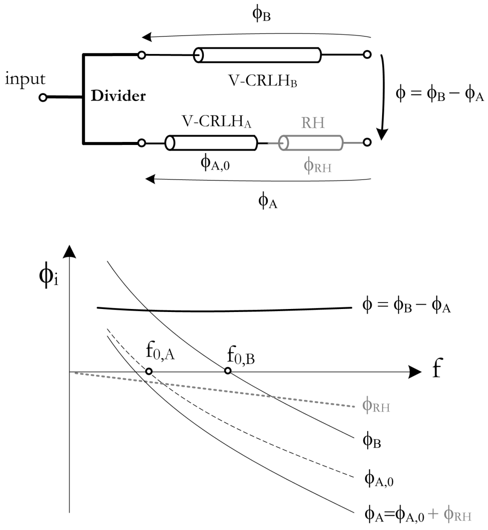

Figure 1: Principle of the MEMS constant-phase shifter (M-CPS).

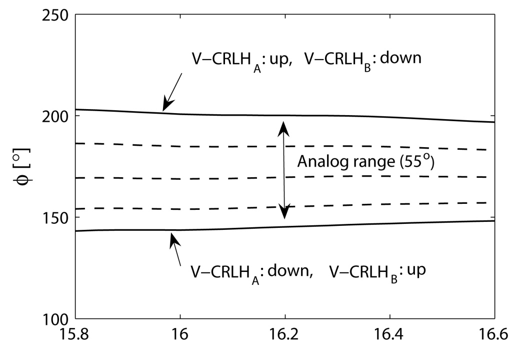

Figure 2: Differential phase shift of the analog M-CPS.