Post-Deadline Contributions

Investigation of Group Delay in Transmission Lines Consisting of Reconfigurable Split-Ring Resonators

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Reconfigurable, multi band devices play an important role in modern wireless systems. A number of papers published so far presents the application of split-ring resonators (SRRs) in design of multi band filters operating simultaneously in two or three frequency bands [1-2]. Despite that concept we investigate different spatial arrangements of split-ring resonators, obtained by rotating individual split-rings, which can be done electronically. It was shown that twisting the angle between SRRs significantly influences the electromagnetic properties and operating frequency range and can be use as additional degree of freedom in design of tunable multi band devices from microwaves to terahertz. [3].

In this work we present theoretical and experimental results of the effective electromagnetic parameters [4-5] for different transmission lines consisting of coupled split-ring resonators. We investigate how the effective electromagnetic parameters and group delay depend on the angle between SRRs. Three different shapes of SRRs: square, rectangular and meander type, which have the same length, are considered in order to maximize group delay per one unit cell. It was shown that unit cells with SRRs placed symmetrically in respect to transmission line exhibit considerably smaller group index n_g ($n_g = \frac{c}{v_g} = n + \omega\frac{dn}{d\omega}$) and consequently the smaller group delay τ_g ($\tau_g = -\frac{d\phi(\omega)}{d\omega}$), than if a little asymmetry is introduced by twisting the resonators by 90 degrees. It is noticed that if mutual position of gaps in square SRRs changes from 0 to 180 degrees in respect to transmission line, the group delay exhibits variation of more than four times (from 0.75ns to 3.1ns). The variation of group delay is even more pronounced in case of rectangular SRRs and reaches almost six times (from 0.78ns to 4.7ns). At the same time group velocity of light can be reduced by factor of 600 with relatively low losses.

In order to verify simulated results, different configurations of SRRs coupled with microstrip line are fabricated and measured in microwave range from 4GHz to 10GHz. The measured transmission and reflection coefficients as well as the extracted effective parameters show a very good agreement with simulations.

REFERENCES

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