

Time-Modulated RF and Microwave Circuits with Periodically Varying Modulation Index

Arkaprovo Das, Manushanker Balasubramanian, Adam Spangler, Pingjuan L. Werner, and
Douglas H. Werner

Department of Electrical Engineering
The Pennsylvania State University, University Park, PA 16802, USA (arka3886@gmail.com)

Time-modulated material systems exhibit extraordinary physical phenomena, such as parametric amplification, non-reciprocal transmission and reception, harmonic generation, time-reversal, temporal aiming, anti-reflection coatings, *etc.* The most common methodology to implement such material systems at RF and microwave frequencies is to utilize time-varying circuits. In its simplest form, these time-varying circuits are practically realizable using diodes and transistors (M. H. Mostafa, N. Ha-Van, P. Jayathurathnage, X. Wang, G. Ptitsyn, S. A. Tretyakov, “Antenna bandwidth engineering through time-varying resistance,” *Appl. Phys. Lett.*, **122**(17), 2023). Applications of time-varying circuits at RF/microwave frequencies are typically designed to operate them in two possible distinct modes: either as ON/OFF switches, or as circuits that change their values sinusoidally in time (*e.g.*, a sinusoidally-varying capacitor or inductor). In this work, we demonstrate a new concept of time-varying circuits whose amplitude variation is also a slow periodic function of time. This implies that the circuit’s modulation index also varies periodically in time, which results in a slowly varying amplitude-modulated envelope function.

Interestingly, it is observed that for the proposed time-modulated circuits with periodically varying envelope, harmonic generation in the vicinity of the carrier signal occurs at discrete integer multiples of three different types of frequencies: modulation frequency, envelope frequency and a linear combination of the two. Further, we also demonstrate a practical PCB based programmable interface using diodes for generating a time-varying capacitance with an amplitude modulated envelope (Fig. 1). The proposed formulation, numerical validation and implementation details will be presented and discussed.

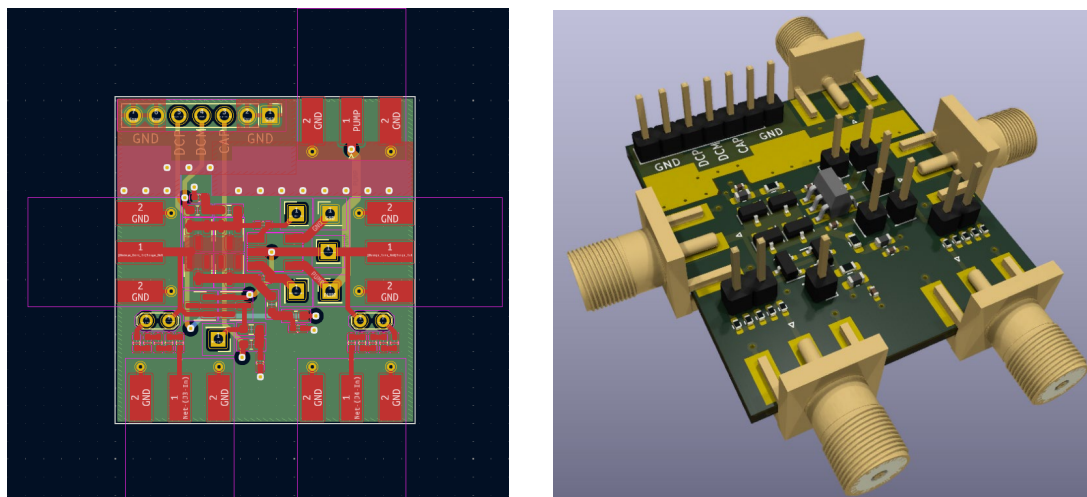


Figure 1. Implementation of a time-varying capacitor with amplitude modulated envelope: 2D PCB layout (left) and 3D conceptual view with ICs and SMA connectors (right).