Varactor Loaded Transmission Lines For Phase Shifting T/M Applications

Capstone Product Proposal - Team 13

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Executive Summary/ Concept of Operations

The objective of the Capstone is to explore the applications of varactor loaded transmission lines as phase-shifters. We will accomplish this by characterizing a varactor over a small frequency range in order to predict its behaviour when scaled to operate at higher frequencies. The main goal of this project is for our models to be accurate enough that scalability is possible. If this goal is reached, optimizing the geometry of the loaded transmission line for the best possible bandwidth and insertion loss would be the next stage.

Brief Market Analysis

Phase-shifting technology is prevalent in phased antenna arrays because of its ability to adjust the directionality of an antenna. Other uses include increasing the bandwidth by lowering the rise and fall time of high-frequency pulses. This is the area in which we will focus on.

TABLE II
COMPARISON OF CONTINUOUSLY ADJUSTABLE PHASE-SHIFTER MMICS

Ref.	*Phase control*	*Band-width*	*Gain/ Ripple*	*Power supply*	*Control voltages*	*Circuit area/ Technology*	*Principle*
[18]	90°	4GHz-6GHz	-1.2dB ± 0.5dB	~0mW	1	0.5mm² 0.6μ GaAs MESFET	Lumped element transmission line PS
[14]	90°	40GHz-60GHz	-4dB ± 0.4dB	~0mW	2	1.5mm² 0.3μ GaAs PHEMT	RTPS with complementary bias
[13]	180°	12GHz-14GHz	-3.6dB ± 1.1dB	~0mW	1	3mm² 0.3μ GaAs MESFET	All pass network type PS using two λ/4 lines
[11]	210°	6.1GHz-6.3GHz	-5.3dB ± 1.4dB	~0mW	1	0.9mm² 0.6μ GaAs MESFET	RTPS
[15]	225°	4.7GHz-6.7GHz	-0.6dB ± 0.2dB	>100 mW	1	0.1mm² 0.1μ InP HEMT	RTPS using active inductors
[16]	360°	5GHz-20GHz	-4.4dB ± 0.6dB	~0mW	1	n. a. large GaAs Schottky Diode	Tuned CPW PS
[10]	360°	2.38GHz-2.42GHz	2dB ± 0.7dB	>90mW	2	2.3mm² 0.3μ GaAs MESFET	Active variable resonant circuit
[7]	360°	4.8GHz-5.8GHz	0dB n.a.	9mW	3	2.4mm² 0.6μ GaAs MESFET	Active vector modulator
[8]	360°	5.1GHz-5.3GHz	0.6dB n.a.	10mW	3	1.3mm² 0.6μ GaAs MESFET	Active vector modulator
[9]	360°	4.7GHz-5.7GHz	-9dB n.a.	~0mW	3	1mm² 0.6μ GaAs MESFET	Passive vector modulator
[12]	360°	5.15GHz-5.7GHz	-6.4dB ± 3dB	~0mW	1	0.9mm² 0.6μ GaAs MESFET	RTPS
[17]	360°	75GHz-110GHz	-5dB n.a.	~0mW	1	n.a. MEMS	Distributed transmission line PS
This work	**360°**	**5GHz-6GHz**	**-4dB ± 1.7dB**	**~0mW**	**1**	**0.8mm² 0.6μ GaAs MESFET**	**Lumped element transmission line PS**

Figure 1: Competing MMIC phase shifters on the market with selected performance characteristics. Taken from (Ellinger, *et. al.*, 2003)

As seen in Figure 1, There are many microwave IC's on the market which primarily focus on a narrow band of phase shifting applications. Instead of reinventing the wheel, Rohde and Schwarz tasked us to fully characterize a model for producing a passive varactor loaded transmission line of a larger bandwidth with minimal losses across all applications.

The goal of this is for us to produce the proof of concept of how realistic designing/creating these modules actually is, and if further investment into this subtopic will be beneficial for Rohde & Schwarz going forward.

Requirements

MUST

- Fully characterize a varactor in MatLab
- Simulate different transmission line geometries in ADS
- Perform memento simulations on transmission line models
- Be modeled based on easily sourced components i.e. Digikey.

SHOULD

- Keep costs to a minimum
- Construct methodology of scaling design for use in higher frequencies
- Construct a scalable model of transmission line
- Design module which optimizes power delivery across the entire bandwidth of operation.
- Design module which optimizes scattering parameters and minimizes undesired signal reflection.
- Design module which creates the shortest output pulses possible to generate higher harmonic content.

MAY

- Construct full scale model with most viable geometry
- Build model with increased bandwidth (DC-64Ghz is the ultimate goal)
- Investigate how circuit block behaves at different ambient temperatures

System Architecture

Do we even need one?

Background

Transmission line basics -

Design Specification

-We need some components, maybe a list of some potential varactors that could be used.

-Maybe include how fast the pulse edge must be to generate harmonics at different frequency ranges.

Deliverables

- Project Proposal
- Weekly Progress Reports to Faculty Advisor
- Detailed and complete documentation for research, modeling data and Simulation results.
- Annotated user manuals such that a future team can easily pick up where we left off.
- Bill of Materials for Modeled Design
- Final Report
- ECE Capstone Poster

Initial Product Design

Verification Plans

-Discuss how we might measure our results in simulation and in real lab settings.

Timeline

Project Gantt Chart

Budget and Resources

Team and Development Process

- Eric Aki
- Juan Rivera-Mena
- Jianyu (Oscar) Hao

Collaboration Tools Methodology

Our team documentation will be found on a private Github Repository (Remind me to add Faust and Greenberg as members so they can view it.)

https://github.com/akier900/Capstone_Rohde-Schwarz_Team13/tree/master/Team%20Schedule

References

Frank Ellinger, Heinz Jäckel, Werner Bächtold, April 2003, *Varactor-Loaded Transmission-Line Phase Shifter at C-Band Using Lumped Elements, IEEE Transactions on Microwave Theory and Techniques*, Vol. 51, Pg. 1139.