Sub-millimetre wave components for steerable antennas with supporting MMIC design

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Overview

• FSS structures
• Reflectarray Antennas
• Quasi-Optical Switches
• V band QPSK MMIC
• Conclusions
Objectives & Why Liquid Crystal?

• **Objective:** Exploit the anisotropic property of Liquid Crystals to create phase shifters for mm & sub-mm wave beamsteering reflectarray antennas which is necessary for space observation objects.

• **Why use liquid crystals >100GHz?**
  - *Thin tuneable LC film (<50µm) means:*
    * Low voltage electronic control ---- easy to be digitally controlled
    * faster switching speed ---- which is important for some applications
    * Device architecture and construction similar to optical LC displays---- fabrication
    * Dielectric anisotropy increases & loss decreases with frequency
    * Low weight, power consumption and cost
Frequency Selective Surface Technology

- Single And Dual Polarisation Beamsplitters At Frequencies Over The Range 100 - 470 GHz
- Single and Multilayer Periodic Structures Designed Using CST Microwave Studio
- Fabrication Uses Precision Micromachining Techniques With Submicron Accuracy
- Spectral Response Measured Using 100 - 700 GHz VNA and QO Test Bench

Example of a Dual Polarisation (TE & TM, 45° Plane) FSS; 316.5 -325.5 GHz/ 349.5 -358.5 GHz

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Fabrication

- SOI Technology 10µm/2µm/525µm – Suitable for Rapid Prototyping
- Deep Reactive Ion Etching (etch rate 3.5 µm/min) – Patterning and Substrate Removal
- Sputter Coated 0.25µm Copper Seed Layer/1µm Electrodeposited Copper
• Transmission Spectra Measured Using 100-540GHz Quasi-Optical Test Bench
  - Reflective Focussing Optics Transforms Gaussian Beam –FSS Positioned at Beam Waist
  - Dielectric Anisotropy Determined by Applying dc Bias
• Linear Polarised FSS Funded by Centre for Earth Observation Instrumentation (CEOI)
• Transmission in Band 440 – 456 GHz (0.25 dB) & Reflection in Bands 314 – 336 GHz (0.8 dB), 239 – 247 GHz (0.22 dB), 174 – 192 GHz (0.1 dB), 113 – 123 GHz (<0.1 dB)
• Slot Length = 326 μm, Width = 20 μm, Thickness = 12 μm
thermotropic liquid crystals

- crystal: 3-D lattice, orientation, solid, anisotropic
- liquid crystal (mesophase): 1-2-D lattice, orientation, fluid, anisotropic
- liquid: no lattice, no orientation, fluid, isotropic
Phase Agile Reflectarray Antennas Based on Liquid Crystals

- Phase Shifters are Created by Exploiting the Dielectric Anisotropy Property of Liquid Crystals
- Parallel Plate Topology Is Suitable for Reflectarray Antenna Design
- Reconfigurable Radiation Patterns Are Generated by Applying a Small Bias Voltage
- Sum and Difference Radiation Pattern Switching Demonstrated at 10 GHz
- Beam Steering Antenna Measured at 94 GHz

Electronically Reconfigurable Quasi–Optical Switches

• A Tunable Bandpass FSS Is Created By Inserting A Thin Layer Of Liquid Crystals Between Two Screens

• Dynamically Switching The Transmitted Signal Between ‘ON’ and ‘OFF’ States Has Been Demonstrated At 145 GHz

• This Structure Can Be Used To Determine The Permittivity, Dielectric Anisotropy And Loss Tangent Of Tunable Liquid State Materials

Summary

- Frequency span, 35GHz~65 GHz
- The phase errors are $\pm 15^\circ$
- The amplitude errors are $\pm 1$ dB
- The insertion loss is 9 $\pm 1.5$ dB
- The input return loss is below -10 dB
- The output return loss is below -10 dB
- The input 1 dB compression power is 18 dBm
- The DC power consumption is below 60mW
- MMIC broadband QPSK modulator
- 0.15 um pHEMT technology
- the chip size is 2.7mm*1mm
The QPSK four states simulated and measured phase performances vs. Carrier frequency for QPSK modulator.
The QPSK four states insertion loss vs. Carrier frequency for QPSK modulator
The QPSK four states input return loss vs. Carrier frequency for QPSK modulator

![Graph showing return loss vs. frequency for QPSK modulator with labels for dB(S(7,7)), dB(S(5,5)), dB(S(3,3)), and dB(S(1,1)).]
The QPSK four states output return loss vs. Carrier frequency for QPSK modulator.
Conclusions

• 450 GHz Bandpass FSS filter with an insertion loss of 0.2 dB
• Sum and difference LC Radiation Pattern demonstrated at 10 GHz
• Beam Steering LC planar array demonstrated at 94 GHz
• Quasi-optical switch demonstrated at 145 GHz
• Broadband millimetre wave QPSK MMIC modulator demonstrated 35 – 65 GHz
Many thanks for your attention

Any questions?