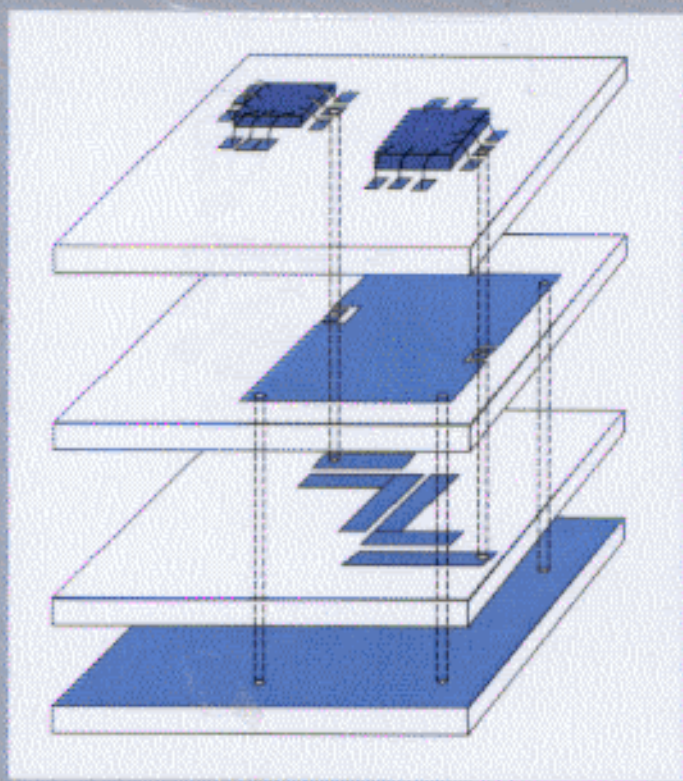


# **Compact Ku-band Transmitter Design for Satellite Communication Applications:**

From System Analysis to  
Hardware Implementation



**Chang-Ho Lee  
Joy Laskar**

# Contents

|                                                         |    |
|---------------------------------------------------------|----|
| PREFACE                                                 | xi |
| 1. INTRODUCTION                                         | 1  |
| 2. KU-BAND TRANSMITTER ARCHITECTURE                     | 7  |
| 2.1 DESIGN CRITERIA                                     | 7  |
| 2.1.1 Modulator Design Criteria .....                   | 7  |
| 2.1.2 Frequency Translator Design Criteria .....        | 9  |
| 2.1.3 Power Amplifier Design Criteria .....             | 9  |
| 2.2 UP-CONVERSION TOPOLOGIES                            | 11 |
| 2.2.1 Direct Up-conversion Scheme .....                 | 11 |
| 2.2.2 Double Up-conversion Scheme .....                 | 14 |
| 2.2.3 Double Up-conversion with Offset Oscillator ..... | 17 |
| 3. TRANSMITTER SYSTEM SIMULATION MODEL                  | 19 |
| 3.1 INTRODUCTION                                        | 19 |
| 3.2 SYSTEM MODEL DEVELOPMENT                            | 19 |
| 3.3 TRANSMITTER MODULE IMPLEMENTATION PROCEDURE         | 25 |
| 4. REVIEW OF KU-BAND MIXERS                             | 27 |
| 4.1 MIXER DESIGN PRINCIPLES                             | 27 |
| 4.2 MIXER PERFORMANCE PARAMETERS                        | 29 |
| 4.2.1 Conversion Gain .....                             | 29 |
| 4.2.2 Conversion Compression .....                      | 30 |
| 4.2.3 Isolation .....                                   | 30 |
| 4.2.4 Dynamic Range .....                               | 30 |

|                                                                     |    |
|---------------------------------------------------------------------|----|
| 4.2.5 Dc Offset .....                                               | 30 |
| 4.2.6 Intercept Point .....                                         | 31 |
| 4.2.7 Noise Figure .....                                            | 31 |
| 4.2.8 Spurious Response .....                                       | 31 |
| 4.3 DEVICE TECHNOLOGIES FOR KU-BAND MIXER .....                     | 32 |
| 4.3.1 Schottky Barrier Diode .....                                  | 32 |
| 4.3.2 GaAs Metal Semiconductor Field Effect Transistors .....       | 34 |
| 4.3.3 GaAs High Electron Mobility Transistors .....                 | 35 |
| 4.3.4 Heterojunction Bipolar Transistors .....                      | 36 |
| 4.4 KU-BAND MIXER TOPOLOGIES .....                                  | 39 |
| 4.4.1 Diode Mixer Topologies .....                                  | 40 |
| 4.4.2 Active FET Mixer Topologies .....                             | 44 |
| 4.4.3 Passive FET Mixer Topologies .....                            | 51 |
| 4.4.4 Other Topologies .....                                        | 52 |
| 4.5 COMPARISON OF KU-BAND MIXER .....                               | 55 |
| 4.6 CONCLUSIONS .....                                               | 57 |
| 5. REVIEW OF KU-BAND VCOs .....                                     | 59 |
| 5.1 OSCILLATOR DESIGN PRINCIPLES .....                              | 59 |
| 5.1.1 Feedback Oscillator (Two-port Model) .....                    | 59 |
| 5.1.2 Negative Resistance (One-port Model) .....                    | 60 |
| 5.2 VCO DESIGN PRINCIPLES .....                                     | 62 |
| 5.3 VCO PERFORMANCE PARAMETERS .....                                | 63 |
| 5.3.1 Phase Noise .....                                             | 64 |
| 5.3.2 Load Pushing and Pulling .....                                | 65 |
| 5.3.3 Thermal Stability .....                                       | 66 |
| 5.3.4 Post-Tuning Drift .....                                       | 66 |
| 5.4 KU-BAND VCO MMIC .....                                          | 67 |
| 5.4.1 YIG-Tuned oscillator .....                                    | 67 |
| 5.4.2 Varactor Tuned Oscillator .....                               | 73 |
| 5.4.3 Tunable Active Inductor Controlled Oscillator .....           | 78 |
| 5.5 KU-BAND GAAS MESFET VCO DESIGN .....                            | 86 |
| 5.6 KU-BAND ALGAAS/GAAS HBT VCO .....                               | 88 |
| 5.7 CONCLUSIONS .....                                               | 88 |
| 6. TRANSMITTER MMIC FOR SATELLITE COMMUNICATIONS APPLICATIONS ..... | 91 |
| 6.1 INTRODUCTION .....                                              | 91 |
| 6.2 TRANSMITTER MMIC DESIGN CRITERIA .....                          | 92 |
| 6.3 DUAL GATE MIXER .....                                           | 93 |
| 6.3.1 Mixer MMIC Design .....                                       | 93 |
| 6.3.2 Measured Performance .....                                    | 95 |
| 6.4 VOLTAGE CONTROLLED OSCILLATOR .....                             | 99 |

|                                                   |     |
|---------------------------------------------------|-----|
| 6.4.1 VCO MMIC Design .....                       | 99  |
| 6.4.2 Measured Performance.....                   | 101 |
| 6.4.3 LO Buffer Amplifier MMIC .....              | 105 |
| 6.5 IF AMPLIFIER MMIC AND RF AMPLIFIER MMIC ..... | 108 |
| 6.6 DRIVER AMPLIFIER MMIC .....                   | 111 |
| 6.6.1 Driver Amplifier Design .....               | 111 |
| 6.6.2 Measured Performance.....                   | 113 |
| 6.7 POWER AMPLIFIER DESIGN .....                  | 115 |
| 6.7.1 Power Amplifier Design Principles .....     | 115 |
| 6.7.2 Linear Power Amplifier Review .....         | 115 |
| 6.7.3 Power Amplifier Design .....                | 116 |
| 6.7.4 Measured Performance.....                   | 118 |
| 6.8 CONCLUSIONS .....                             | 119 |
| 7. TRANSMITTER MODULE DESIGN .....                | 121 |
| 7.1 INTRODUCTION .....                            | 121 |
| 7.2 STRIP LINE BAND PASS FILTER .....             | 121 |
| 7.2.1 Strip Line Filter Design Principles.....    | 121 |
| 7.2.2 LTCC-based Strip Line Filter Design .....   | 124 |
| 7.2.3 Measured Performance.....                   | 129 |
| 7.3 MODULE DESIGN .....                           | 130 |
| 7.4 MODULE MEASUREMENT RESULTS .....              | 132 |
| 7.5 CONCLUSION .....                              | 137 |
| 8. CONCLUSION .....                               | 139 |
| BIBLIOGRAPHY .....                                | 141 |
| INDEX .....                                       | 159 |