Design of a Ka-Band Beamformer for Transmitting Active Phased Array Antennas for Satellite Communications

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Abstract— Recent rapid advancements in wireless communication technology have led to significant developments in satellite communication as well. Satellite communication offers advantages such as the ability to transmit information over wide areas and enable simultaneous communication with multiple users.

In this paper, a beamformer design is proposed for communication with Ka-band satellites, featuring low noise and high gain characteristics. The presented beamformer follows an LCA-PS-LCA-DSA-PA architecture to be used for transmitting Active Phased Array Antennas.

The design was implemented using CMOS fabrication processes, resulting in a compact size and cost-effective solution.

The Loss Compensation Amplifier (LCA) is placed to meet wireless link budget requirements, particularly compensating for a loss of around -12dB in the Phase Shift stage. To minimize noise and parasitic components, the input and output are designed in a differential structure. The Output Stage employs capacitive neutralization techniques to counteract parasitic capacitance and achieve low impedance loading with a differential 100-ohm configuration.

A Digital Step Attenuator (DSA) is integrated for variable gain control of the transmitter. For very small attenuation values, the resistance of the serial switch and the characteristics of the transistor can be ignored. As a result, these components were removed, and a simplified attenuator was implemented. This reduces loss and minimizes parasitic capacitance, ensuring broad bandwidth characteristics.

For phase adjustment of the transmitted signal, a Phase Shifter(PS) is used. A simplified Phase Shifter design is employed, relying solely on capacitors for phase shift at very small values, eliminating the need for inductors and thus reducing losses and parasitic capacitance. A modified Bridged-type Phase Shifter structure is also used by adding capacitors to expand the bandwidth.

The Power Amplifier (PA) design uses a common-source amplifier architecture and employs Capacitance Neutralization techniques. Through the Cross-Coupled structure, the parasitic capacitance arising from the increased size of the transistors was mitigated, ensuring high-frequency performance and maintaining linearity.

Both the PA and LCA active components adopt a 3-stage structure to meet performance requirements.

The overall size of the transmitter is 4,280 x 800 µm². It consumes a current of 157.32mA at a power supply voltage of 1.2V. Measurement results indicate that the transmitter achieves a Gain of over 50dB and linear Bias Control in the 27.5~31GHz frequency range. OP1dB is approximately 10dB, while IP1dB was measured around -50dB.

Keywords—Satellite Communications, Array Antennas, Ka-Band, Beamformer, Transmitter, Loss Compensation Amplifier, Phase Shifter, Digital Step Attenuator, Power Amplifier

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