ABSTRACT

The major limitations of high range and high-resolution radar at microwave and millimeter wave frequency is the unavailability of compact, efficient high-power source with low distortion using solid state devices. Currently the most promising solid-state technology for high power handling is GaN/AlGaN based high electron mobility transistors (HEMT) at microwave and millimeter wave frequency. A key advantage of GaN is its ability to maintain high operating voltage at higher frequency range. Due to high mobility and high saturation velocity these transistors can be operated at microwave and millimeter wave frequency. These devices can handle high voltage due to the wide band-gap of GaN and have high carrier density due to polarization effects in GaN/AlGaN heterostructure. Hence these devices have high power handling and high-power generating capacity with less distortion at microwave and millimeter wave frequency range.

This thesis work is focused on developing GaN/AlGaN HEMT based High power sources using active integrated antenna (AIA) approach. One goal of this thesis is to develop a high-power amplifier type AIA. While most reports on GaN HEMT concentrate on power amplifiers, this design also combines AIA approach with power amplifier design to make the system compact and increase effective isotropic radiated power (EIRP). The measured EIRP of this circuit is 49 dBm, which is better than the state-of-the-art results reported for GaN HEMT based active integrated antenna.

The second goal of this thesis is to develop GaN/AlGaN HEMT based self-oscillating AIA. This oscillator design is based on negative impedance technique and AIA approach. Here the patch antenna is connected at the output side of the oscillator and performs multiple functions and makes the system compact. It acts like a load, resonator and radiator. The two circuits using the same approach are developed using a single device. The measured EIRP of the first circuit is 18 dBm at 1.5 GHz. The measured EIRP of the second circuit is 29 dBm at 2 GHz frequency.

The third goal of this thesis is to develop GaN/AlGaN HEMT based self-oscillating AIA, where the AIA approach is used to maximize the radiated power at second harmonic. Hence the frequency of power generation is doubled. Two circuits are designed for this purpose. The measured EIRP of the first circuit is 32 dBm at second harmonic (3 GHz) and

16 dBm at fundamental frequency (1.5 GHz). In the second circuit the negative impedance region (frequency) is increased using a coupled line in parallel with the device, the AIA approach is also used to maximize the radiated power at second harmonic. So, this circuit generates high power at higher frequency. In simulation this circuit has simulated power of 37 dBm at second harmonic of 8 GHz and 20 dBm at fundamental frequency (4 GHz). So, the proposed GaN HEMT based AIA concept can be used to generate useful power at higher frequency and this technique will be very useful in extending the frequency of operation of circuit beyond the operating frequency range of transistors used in the circuit.

The final goal of this circuit is to develop GaN/AlGaN HEMT based self-oscillating fixed frequency and frequency reconfigurable AIA high power source using feedback topology. The fixed frequency circuit implemented radiates 41 dBm power at 2.4 GHz, which is the highest EIRP using a single device. In frequency reconfigurable AIA, the frequency of oscillation changes from 2.1 GHz to 2.7GHz, when pin diodes change its state from off state to on state. The circuit has EIRP within 1dB in both states. This circuit is very compact and can generate two frequencies by changing the biasing of pin diodes without changing the circuit footprint. This circuit is the first implementation of GaN/AlGaN HEMT based reconfigurable oscillating AIA.

Due to the above-mentioned design concept and approaches on design level, this work provides the basis for the design and implementation of GaN/AlGaN HEMT based high power sources at microwave and millimeter wave frequency. Also, the power can be further increased using spatial power combining technique. Therefore, GaN/AlGaN based high power circuits are of great interest for long range solid-state phased-array systems.