Design and Development of Ku- and Ka-band Ultra-Wideband Radars for

Radar System Description

Both radars will operate in the Frequency-Modulated Continuous Wave (FM-CW) mode with a transmit power of only about 10 mW. We will generate an ultra-fast and ultra-linear chirp over 12-18 GHz using a phase-locked voltage-controlled oscillator with a low-frequency digital reference chirp generated with an arbitrary waveform generator (AWG). The 12-18 GHz chirp signal will be split into two parts. One of these parts will be used for the Ku-band radar and the

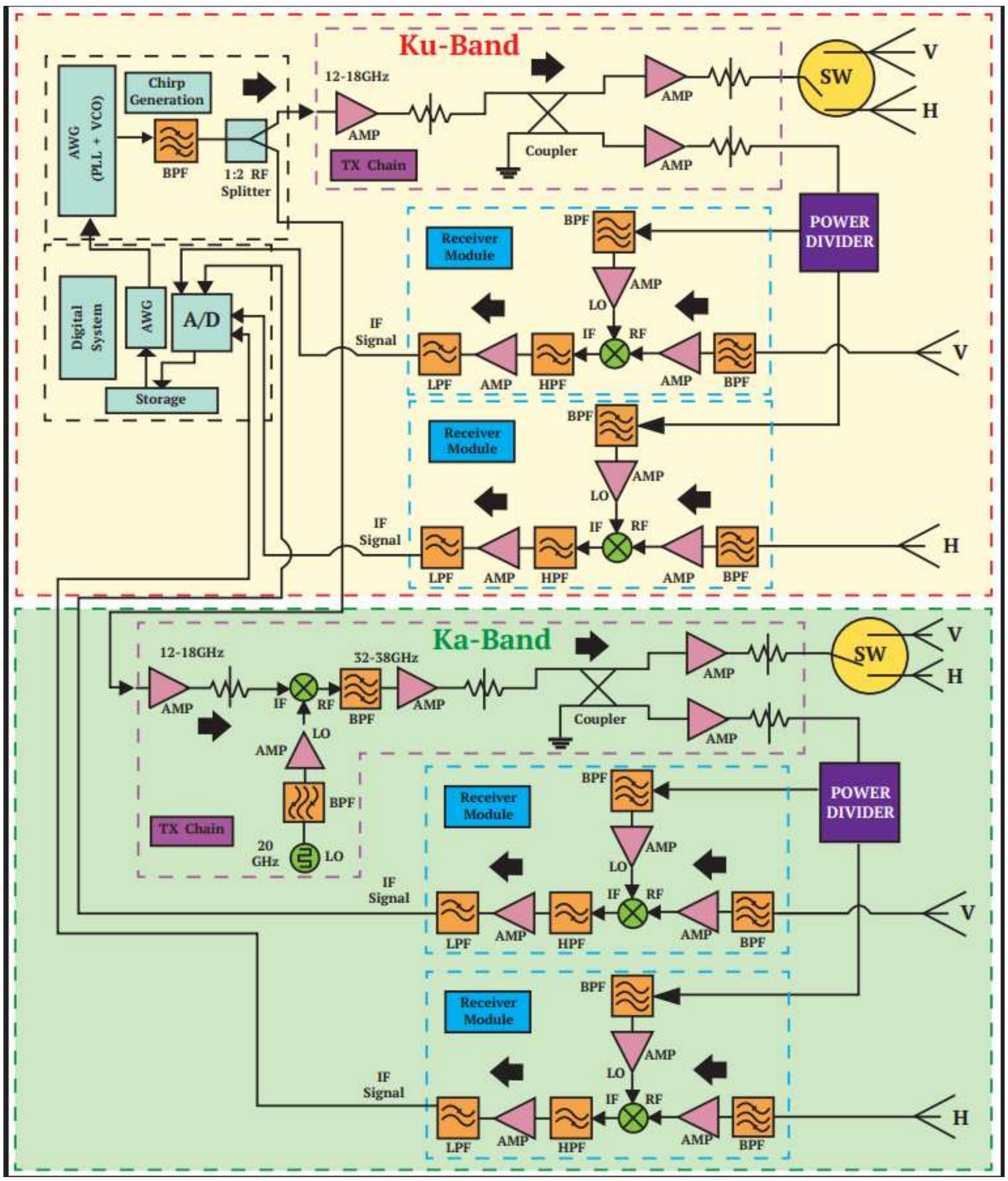

Figure 4: Simplified system block diagram of the proposed Ku-band Radar and Ka-Band radars

other part will be up-converted into 32-38 GHz for the Ka-band radar. We will use separate transmit and receive antennas to obtain high isolation between the transmitter and the receiver.

Figure 4 shows the simplified system block diagram of the proposed dual-band polarimetric radar system. The transmitter and receiver sub-sections of Ku-band and Ka-band radars will be very similar except for the Ka-band chirp signal is obtained by up-converting the 12-18 GHz chirp by mixing it with a 20-GHz local oscillator signal. The transmitter sub-section consists of a driver amplifier to increase the power level and the driver-amplifier output is supplied to a power divider to split the signal into two parts. One of the parts serves as the transmit signal and the other serves as the local oscillator (LO) signal to a mixer. The transmit signal is further amplified with a power amplifier and supplied to the dual-polarized transmit antenna array through a single-pole double-through (SPDT switch) and an attenuator. The critical components in the transmit section are padded with 3-6 dB attenuators to reduce multiple reflections.

The LO signal is split into two parts: one of these parts is amplified and supplied to the mixer for the like-polarization (VV or HH) receiver and the other part is also amplified and supplied to the mixer for the cross-polarization (VH or HV) receiver.

The dual-polarized receive-antenna captures both like- and cross-polarization reflected and scattered signals. The receiver sub-section consists of two identical receivers: (1) one for VV and HH polarizations and the other for VH and HV polarizations. Each receiver consists of a low-noise amplifier (LNA), a mixer to down-convert received signals to an intermediate frequency (IF), and a bandpass filter (BPF). We will develop the BPF using a high-pass reflectionless filter and a low-pass reflectionless filter. We will use an LNA with about 15-dB gain and high reverse isolation of 30 dB or more to minimize radiation of LO signals, leaking into the RF port of the mixer because of the finite isolation between LO and RF ports, by the receive antenna. Most mixers with low third-order intermodulation products require LO signals in the 13-15 dBm range for proper operation. The isolation between a typical mixer RF and LO ports is between 20 and 30 dB. The LO leakage signal at the RF port (-15 to -5 dBm), which is only 15-25 dB below the transmit signal, can be radiated by the receive antenna. The LNA will reduce this leakage signal by about 30 dB to minimize its impact on radar sensitivity. The careful analysis, design, and simulations to optimize our radars allowed us to develop thermal noise limited systems [1]. We will use a similar approach to develop Ku- and Ka-band radars. The mixer in the receiver generates beat-frequency signals, referred to as intermediate frequency (IF) signals by mixing a sample of the transmit signal with received signals.

The radar IF section consists of a reflectionless high-pass filter (HPF), an IF amplifier, and a reflectionless lowpass filter (LPF). The HPF reduces strong low-frequency feedthrough signals from saturating the IF amplifier. The filtered signals are amplified to a level required for digitization. The LPF reduces transmit and LO signals coupled into the mixer IF port, and also serves as an anti-aliasing filter for the digitizer. The filtered signals are supplied to 14-bit A/D converters for sampling at 250 MHz in the digital subsystem for digitization and storage.

Chirp Generator

We already developed an ultra-linear Ku-band chirp generator with a chirp of 200-250 us. It consists of a 12-18 GHz VCO, a divider, PLL, AWG, and FGPA. The FPGA generates the tuning voltage required to linearize the VCO and this voltage is applied to the VCO tuning port through a summing amplifier. A sample of VCO output signal (12-18 GHz) is applied to an integer 16-divider to obtain a signal in the 0.75-1.5 GHz range and supplied to the PLL chip with an internal divider set to divide further by 4. The internal divider output signal in the frequency range of 187.5 — 375 MHz. This signal is compared with reference chirp (187.5-375 MHz) generated with an arbitrary waveform generator (AWG). We selected the AWG to generate reference chirp because we can pre-distort the reference chirp and correct for any system delays. The error signal from the PLL is filtered, amplified, and summed with the tuning voltage to correct the VCO for any deviations from a perfect linear tuning response.

We generated a 5-GHz bandwidth chirp at 200-250 us chirp rate using the setup shown in Figure 5. The response for a point target located at a range of 200 m is shown in the bottom left inset and the expanded response around the target peak is in the center inset of Figure 5. The close agreement between the ideal and measured responses for the main lobe and the first two sidelobes shows that we successfully generated an ultra-linear and fast chirp signal. The disagreement beyond the second sidelobes is related to digitizer noise. We are now developing a single board that contains all sub-systems needed, instead of using evaluation boards, to generate the chirp and expand it to a 6 GHz bandwidth.