AN5: Millimeter-Wave Radar Subsystems

Applications:

Millimeter wave radars are employed in a wide range of commercial, military and scientific applications for remote sensing, safety, and measurements. Millimeter wave sensors are superior to microwave and infrared-based sensors in most applications. Millimeter wave radars offer better range resolution than lower frequency microwave radars, and can penetrate fog, smoke and other obscurants much better than infrared sensors. Some of the most commonly employed millimeter wave radar subsystems are:

- Automobile Collision Warning sensor
- Autonomous Cruise Control
- Robotic vision
- Surveillance - Air Defense, Sniper/Artillery location-tracking
- Altimeters and Height/depth measurement
- Missile guidance and tracking
- Speed and range measurement for industrial uses
- Industrial depth measurement in hostile environment
- Severe weather studies and measurement
- Clear Air Turbulence/Wind Field measurements
- Wide area traffic monitoring and control
- Intrusion detection
- Aircraft collision warning/obstacle detection system for helicopters, Unmanned Aerial Vehicle (UAV), Unmanned Surface Vehicle (USV)
- Harbor monitoring/Navigation guidance
- Imaging
- Vision/sensing in adverse weather/environment
- Presence/motion Sensors for automated systems
- Safety and security devices

Description:

Millimeter wave radars are generally classified in two broad categories with several specific variations or modes of operation associated with each type:

Pulsed Radars:

- Coherent Pulsed
- Doppler/Moving Target Indicator
- Incoherent Pulsed
- Pulse Compression (FM/PM/Polarization diversity)

CW radars:

- Doppler
- Freq. Modulated (FMCW)
- Phase Modulated and Multi-frequency waveform

In each case, the radar determines the size, characteristics, range and velocity of the object or scene by measuring the characteristics of the return signal after reflection/scattering from it. The amplitude, spectral contents and the time of arrival of the return signal yields the necessary information regarding the observed scene or object.

A basic comparison of the two types or modes is presented in Table A

Requirement or Feature	CW Radars	Pulsed Radars
Hardware Complexity	Simpler	More Complex
Short range target Detection	Superior	Better for longer ranges
Moving target discrimination	Inherent capability. Easy to realize	Not trivial to implement. Requires sophisticated signal processing. Doppler frequencies that are multiples of pulse repetition frequency are difficult to detect/measure
Target range Discrimination	Moderate	Superior due to narrow pulse width and other techniques
Transmitter-Receiver Isolation	Moderate (20-25 dB) for monostatic (single common antenna)configuration. High (>50 dB) for bistatic antenna configuration	Inherently High

Figure 1 (a) and (b) show the basic architecture of these two types of radars. The most important element in any radar is the transmitter source (which often also serves as the local oscillator source) for the equipment. The transmitter signal could be CW, pulsed or modulated with one of many specific radar waveforms. Received signal can pre-amplified using a low-noise amplifier, if desired for enhanced sensitivity or range. Radar receiver or downconverter produces the appropriate intermediate frequency or baseband radar return signal, which in turn is amplified, filtered and processed by radar signal processor to generate the information or image.

Figure 1(a): Direct Pulse Modulation Scheme

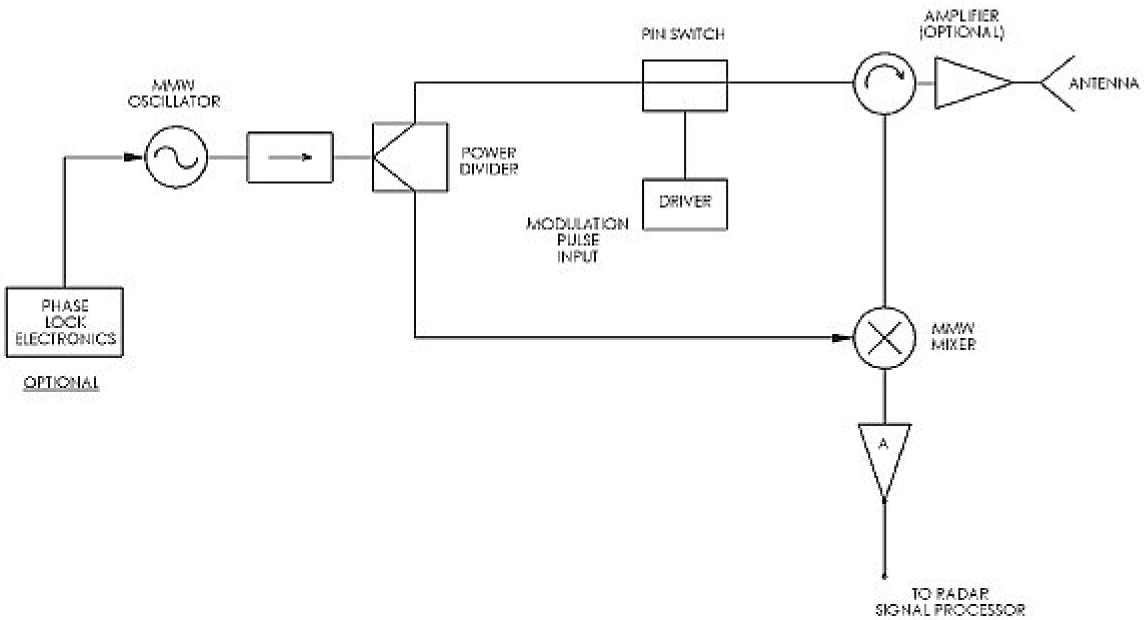
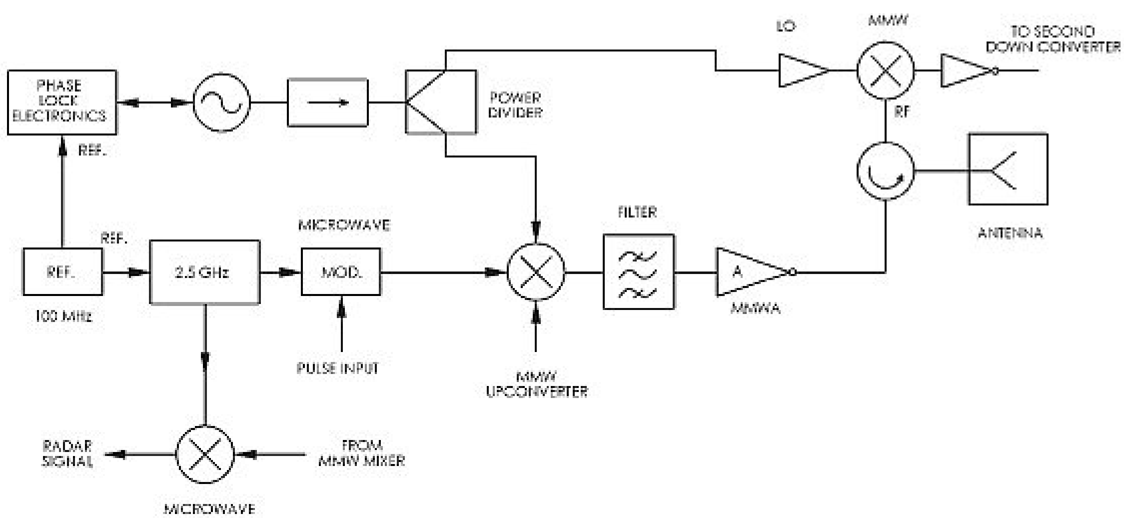
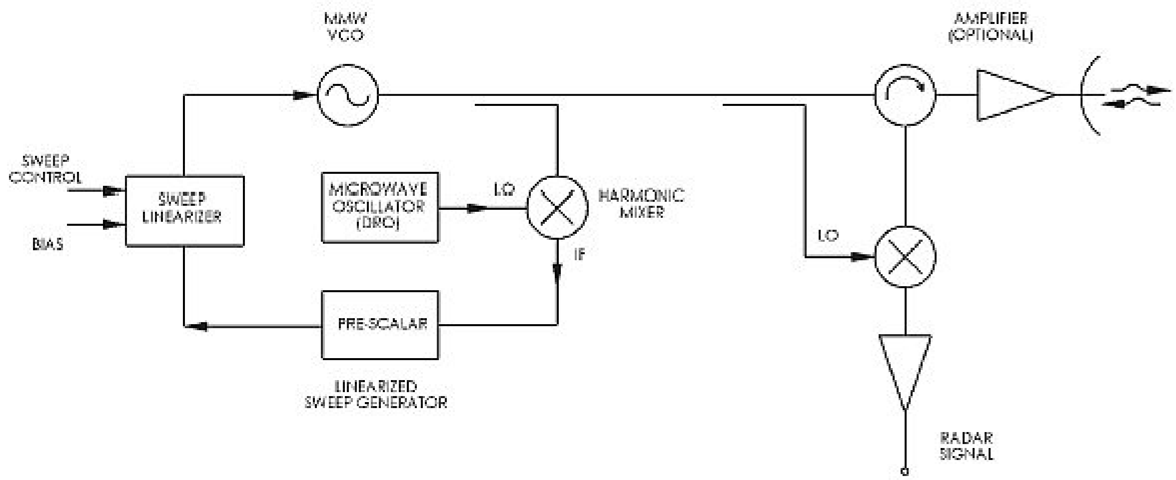


Figure 1(b): Upconverter Signal Scheme



Option C: Free-running Transmitter with receiver AFC



Operation and Typical Performance Characteristics:

Pulsed radar are generally coherent radars, and use a stable lower frequency source as reference signal. They normally use a single antenna for transmit and receive functions (mono-static configuration). A modulator is generally employed to create the required radar pulses and waveform as well as any frequency agility, if needed. A short pulse (from a few microseconds to a few nanoseconds) of millimeter wave is generated by the transmitter module and fed to the antenna. The return signal is routed to the receiver by a duplexer such as a circulator. If necessary, receiver protection and limiting functions are incorporated in the receiver front end.

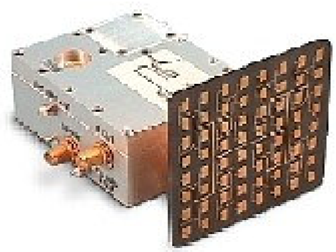
Low phase noise contents of the transmitter signal and of any local oscillator used in the receiver is essential to the operation of the radar. Depending on the range, sensitivity and resolution and other requirements, the phase noise plays a vital role in determining the capabilities of the radar.
CW and FMCW radars typically transmit a continuous wave signal, which could be frequency modulated or chirped/swept. If frequency modulated, the linearity and bandwidth of the sweep is critical in determining the accuracy and the resolution of the radar. An FMCW radar can be configured as either mono-static or bi-static (single or separate antenna for transmit and receive functions). The local oscillator signal in this type of radar is generally the same) as the transmitter signal, and is derived by splitting the power from the master source of the radar.

Typical Examples and Case Histories:

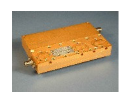
Frequency and Type	Description	Application and Comments
35 GHz FMCW	Ultra-linear sweep, High Power Output, Integral single antenna with duplexer, Compact package	Detection of intruders and moving vehicles, security, obstacle detection for robotic equipment, traffic monitoring and control. See Photograph

76.5 GHz, FMCW	Employed waveguide-based components for low-cost rapid prototyping. Integrated antenna subsystem to create three narrow beams and one broad beam. Optional monopulse configuration offered. Power output options from 10 mW to greater than 100 mW. Highly linearized sweep (<0.1% linearity, 400MHz sweep-width)	Prototype radar for automobile collision warning, security and perimeter protection, robotic vision/ranging. Traffic monitoring/detection.
76.5 GHz, multi-mode	Highly integrated package	Automobile Collision Warning and Autonomous Cruise Control
94 GHz, Pulsed	Multi-Watt, narrow pulses (100 nS) (Cohert and free-running versions)	Missile Guidance and Collision Avoidance
94 GHz FMCW	Utilizes upconverter for introducing waveforms and frequency agility. Highly linear and stable operation. Output power options from 10 mW to 1 W CW.	Research radar for study of severe weather and clouds. Development and instrumentation radar. Military applications
35 GHz	Ultra-miniaturized packaging, integral antenna feed, very high power output (> 1Watt CW). Rugged, robust.	Military seeker and sensor applications for munitions and missiles.

TSC, 35 GHz Multichannel High Resolution Radar



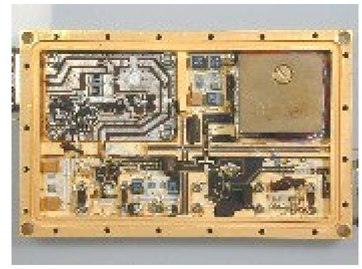
Ultra-Linear 35 GHz FMCW Tranceiver Module with Integral Printed Circuit Antenna



External view of 76.5 GHz Collision Warning Radar Transceiver

W-Band Transceiver in Customer's Cloud Measurement Radar

76.5 GHz FM-CW Transceiver for Vehicle Radar Application



76.5 GHz Collision Warning Radar Transceiver, Internal View

QuinStar Components and Products Used

Amplifiers (Low Noise, Power)
Antennas
Balanced Low Noise Broadband Mixer
Detectors
Feed horns
Frequency Multipliers
Microwave (IF) Amplifiers
Oscillators (Gunn Diode Oscillator, series QTM from 18-150 GHz
Phase Locked Sources and Electronics
Power Dividers/Hybrids (Short Slot Coupler, Matched Hybrid Tee, Directional Couplers)
Switches (PIN, electromechanical)