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Ka-Band Target Tracking Radar Sensor

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Abstract
This paper briefs the monopulse principle and an improved technique for the application of target tracking radar system. A Ka-band sensor module for this type of radar has been developed by using the separated T/R antennas and the direct I-Q demodulate receivers. Some design considerations are discussed on the functional diagram level.

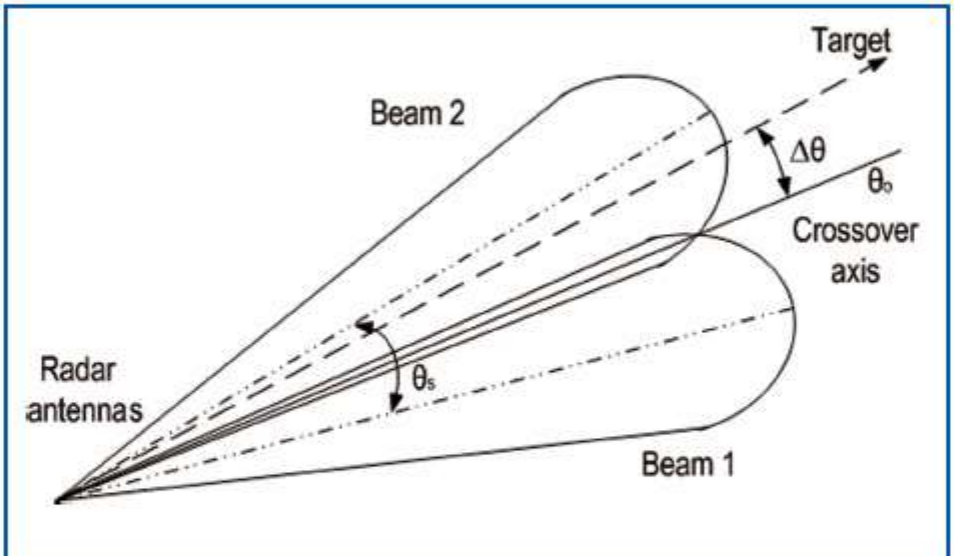

Figure 1: Antenna patterns for amplitude-comparison (Σ-Δ) monopulse system

Introduction
Different from a search radar, tracking radar automatically keeps its beam axis pointed towards a selected target. The most commonly used technique in the tracking radar is monopulse, also known as simultaneous lobe comparison. The output of the monopulse radar can be used open-loop, in combination with the known direction of the beam axis, to determine target angle, or fed back in a closed loop to control the direction of the beam so as to keep the axis pointed as closely as possible towards the target.

Monopulse does not necessarily operate on “one pulse” as the name implies. The term originated from its inherent capability to produce a two-coordinate angle measurement from each pulse. As a matter of fact, monopulse does not require the use of pulse at all. It can operate with continuous waveform (CW) mode or modulated CW mode.

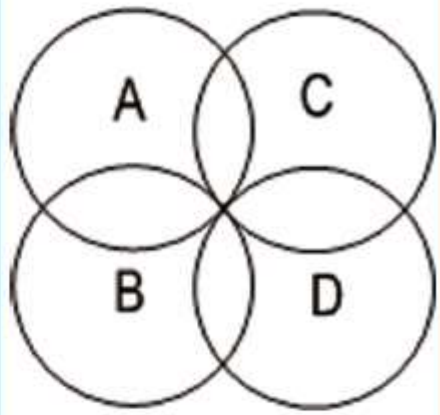

Figure 2: Cross section of amplitude-comparison monopulse beams

Most tracking radars used today are of the monopulse type. They perform a large variety of functions in fire control, missile launch and guidance, strategic military applications, space applications, intelligence and instrumentation.

Principle of Operation
The three main monopulse techniques for target angle sensing are amplitude-comparison, phase-comparison and the combination of the amplitude and phase comparison. They are classified by how the angle discriminator of the system responds to the relation of amplitude, phase or the combination of both respectively.

Figure 1 shows the fundamental operating principle of the amplitude-comparison monopulse technique. For one angle of coordinate measurement, the monopulse system obtains the angular information of a target by comparison of signals simultaneously in two antenna patterns. If the target is on the crossover axis of the overlapping patterns (the solid line), echo amplitudes received are the same in beam 1 and 2. If the target is above the crossover axis (the dashed line), the echo from beam 1 is greater than from beam 2. By adding and subtracting the echoes from the two antennas, two resulting signals, sum (Σ) and difference (Δ), are obtained. The received sum signal is used for target detection, range measurement, and as phase reference for determining the sign of angle error measurement. The angle error measured in reference to the antenna crossover axis is determined from the difference signal. In order to determine the target direction, the above antenna system must exist for every angular coordinate. In this case, another similar receiver chain for the difference (Δ) should be added to produce the angle information for the other angle coordinate. For simultaneous measurement in azimuth and elevation, the system needs to have two pair of antenna. The four beams' cross section is shown in **Figure 2**. The sum and differences are:

$$\Sigma = 1/2\ (A+B+C+D)$$

$$\Delta_{azimuth} = 1/2\ [(C + D) - (A + B)]$$

$$\Delta_{elevation} = 1/2\ [(A + C) - (B + D)]$$

Design Consideration
In practice, the antenna or antenna array in the monopulse system can be either square or rectangular, depending on the beam and polarization requirements. Identical, or equal, radiation patterns are the only requirement for them. These antennas are positioned symmetrically with respect to the antenna system axis.

In the sensor design, shown in the block diagram of its RF section (**Figure 3**), the transmitter antenna has been separated from the receiver antennas in order to obtain better T/R isolation as well as the CW mode operation. The use of modulated CW waveform transmission relaxes the high linearity requirement of the VCO design. In fact, no VCO is needed in the design. Only the low cost Gunn oscillator is used as the source of transmitter, and the receiver LO. The transmitter CW modulation arrangement also increases the maneuverability of transmitting a signal for both amplitude and phase.

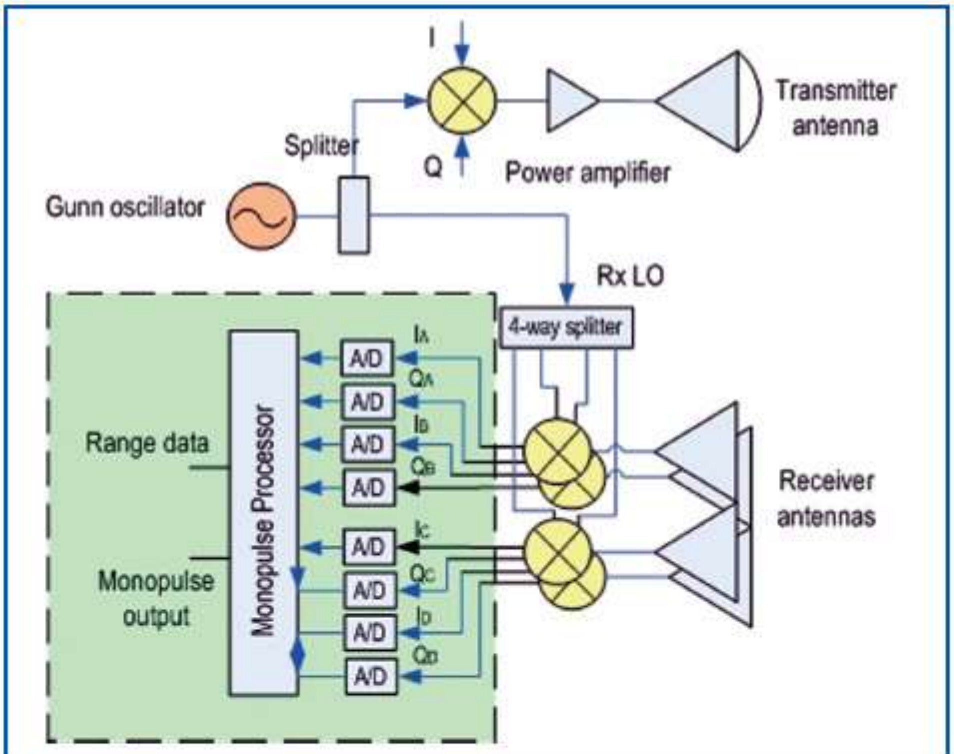

Figure 3: Functional diagram of the monopulse radar system

What is new in the receiver design is to use I-Q mixers to convert received RF signals directly down to base band I-Q signals, which is different from conventional hybrid junction design in terms of hardware complexity. In the conventional design, where the hybrid junction is used, the monopulse processor uses the sum voltage and two difference voltages at the output linear receivers. Sometimes logarithmic amplitude and phase detectors, instead of linear receivers, are used to increase the dynamic range. With the new design proposed here, in which no hybrid junction components are involved, the I-Q signals from four receiver channels can be directly A/D converted and digitally processed by the monopulse processors. The I-Q monopulse processor uses the real (I) and imaginary (Q) parts of the receiver outputs, instead of sum and difference vo ltages, to derive the range data and angle error information. The hybrid junction function is completed in the monopulse processor. Although the individual system calibration makes the DSP software more complex, the incremental DSP development cost is negligible in comparison with the savings of hybrid junctions and other hardware. The other advantage of this direct I-Q design is the absolute phase of the LO oscillator.

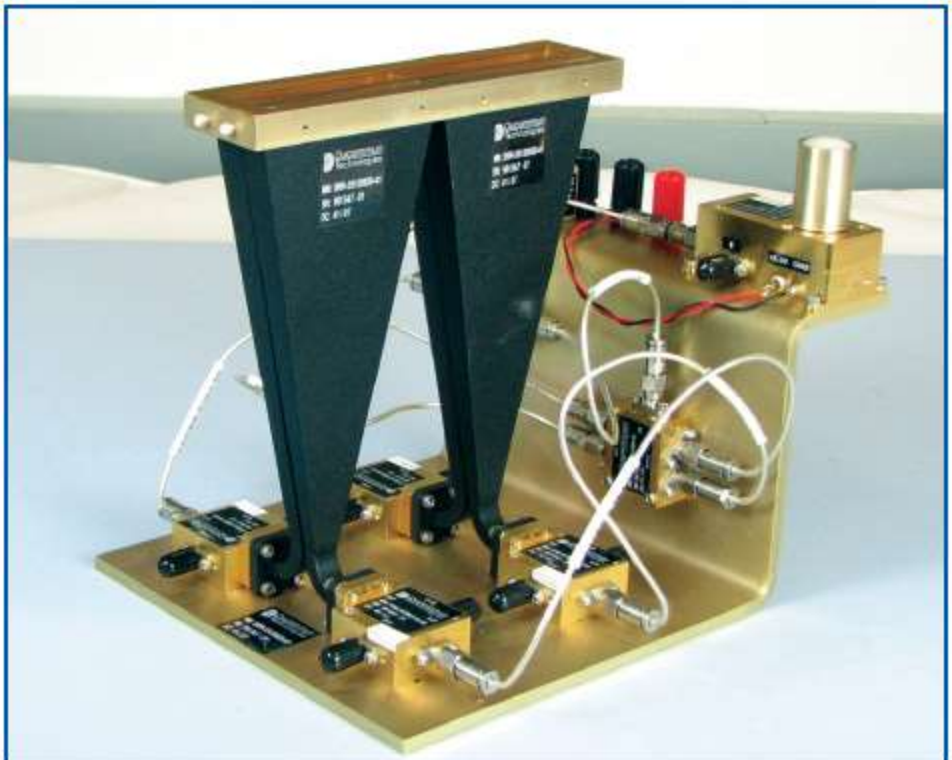

Figure 4: The developed module

RF Sensor Development

Ducommun has successfully finished the development of the Ka-band sensor module including antennas, as shown in **Figure 4**, for an application of target tracking radar system. The following are the major specifications for the module (Ducommun part number SSS-35120920-41):

Frequency:
35.0GHz
TX IF Modulation:
DC to 50 MHz (Min)
Transmitter Output Power:
20 dBm
Receiver Conversion Loss:
10 dB
IF Bandwidth:
DC to 50 MHz
TX Antenna 3 dB Beamwidth:
30 Degrees

Polarization:
Right Hand Circular
Rx Antenna 3 dB Beamwidth, H-Plane:
10 deg.
Rx Antenna 3 dB Beamwidth, E-Plane:
45 deg.
Bias:
+8.0 V / 2000mA (max)
RX Output Connectors:
SMA (F)