WHITE PAPER

ALTUM RF

Cost-effective Front-end Components for X- and Ku-Band Phased Array Radar

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Abstract

This paper looks at common system architectures for short- to medium-range AESA radars, with a focus on the front-end components used to enhance system performance. These components include the power amplifier (PA) for transmit, the low-noise amplifier (LNA) for receive, and the transmit-receive switch to connect the antenna to the electronics. Key features include the different power levels, frequency bands, and compact size required to use these systems in urban areas.

Introduction

The transition from conventional radar, with a parabolic dish antenna and TWT power amplifier, to the more modern active electronically scanned array (AESA) radar, using a planar antenna and solid-state amplifier, has evolved over the past 20+ years. Recent advancements in digital signal processing and software-defined radio semiconductor technology have also aided the advancement of AESA radars [1].

The benefits of AESA radar include more detailed range of detection, better resistance to jamming, better reliability with less risk of complete system failure, multi-function radar and communication capabilities, and the ability to calibrate and optimize the radar performance with software. The disadvantages include the increased complexity and difficulty in manufacturing, not being able to scan a full 360° with a single antenna (AESA radars typically span 120°), and cost, which has been coming down with the integration of advanced ICs using surface-mount technology (SMT) for assembly [2].

One area of recent growth for AESA radar is in the very short- to medium-range segments (<10 km to 200 km). The rise of drone and UAV activity has driven demand for both commercial and defense applications for purposes of security and surveillance [3,4]. The need for additional monitoring and surveillance has been illustrated by incidents in the air transport industry, such as the drone interference at London's Gatwick airport in 2018 that cancelled some 1,000 flights and stranded 140,000 passengers over the course of three days. Professional soccer matches, college football games and other sporting events have been halted, delayed, and even cancelled due to unauthorized drone activity.

To detect and track smaller objects such as drones or UAVs, a different kind of radar is needed—different than the more traditional military radars that are searching for larger objects such as aircraft or missiles. AESA radars are being developed for tracking smaller objects at shorter range using X-band and Ku-band frequencies. Off-the-shelf semiconductor components are now available to enable these applications, such as the digital signal processor/data converter, analog beamformer, and integrated front-end components.

This paper looks at common system architectures for short- to medium-range AESA radars, with a focus on the front-end components used to enhance system performance. These components include the power amplifier (PA) for transmit, the low-noise amplifier (LNA) for receive, and the transmit-receive switch to connect the antenna to the electronics. Key features include the different power levels, frequency bands, and compact size required to use these systems in urban areas. Some devices developed by Altum RF to address the RF front-end requirements will also be highlighted.

Short- to Medium-Range AESA Radar

The key components in an AESA radar system include the digital signal processing IC, the analog beamformer IC, the front-end components, and the antenna elements. The DSP IC handles complex signal-processing in the digital domain, including digital beamforming for some systems. The data converters are usually contained in this IC, which does the high-dynamic range conversion from analog to digital, and digital to analog. The analog beamformer IC controls the magnitude and phase of the signal to each antenna element and usually contains multiple channels to feed multiple elements plus handle horizontal and vertical polarizations.

The front-end components include the PA, LNA and switch. This can be accomplished with separate components or an IC or module. The integrated solution has the benefits of smaller size and ease of manufacturing where the individual components provide more flexibility and faster time to market if an integrated solution is not available. The front-end components include the PA that boosts the transmitted signal, the LNA that receives the return signal while adding minimal noise when boosting the signal power, and the transmit-receive switch that connects the electronics to each antenna element. A radar system like this will typically require on the order of 500-1500 antenna elements. A significant amount of software is also required to optimize and calibrate the radar performance for the antenna beam-steering and signal-processing of the returned signal. These electrical functions are illustrated below in *Figure 1*.

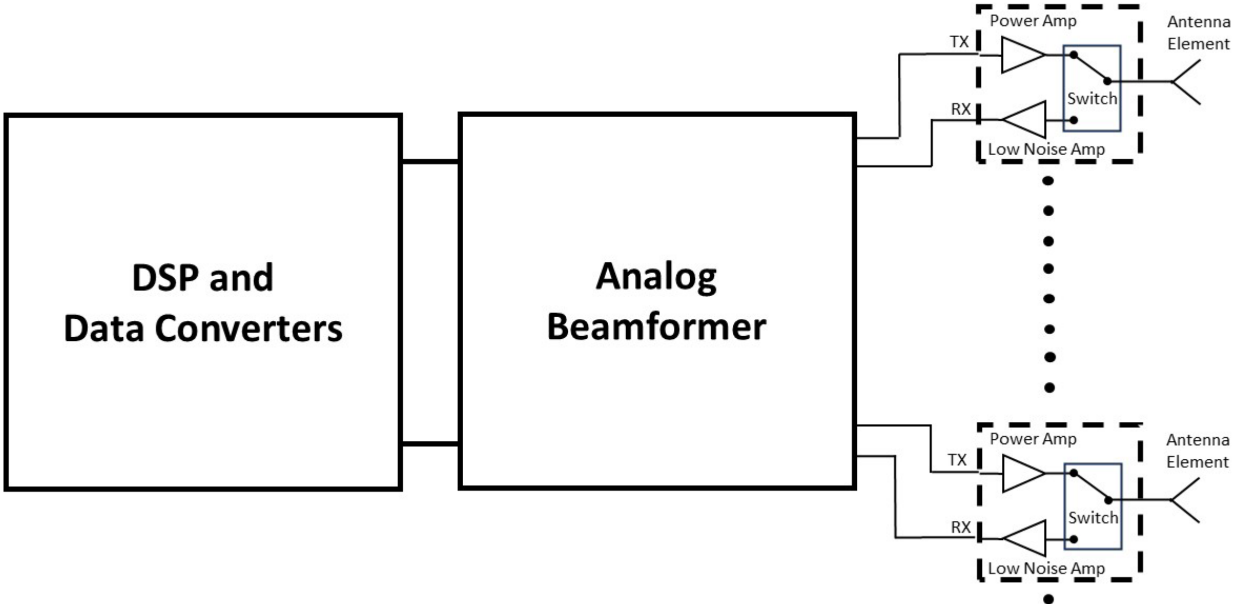

Figure 1: AESA Radar Electrical Block Diagram

Requirements for Front-End Components

AESA radars can have enhanced performance through the addition of higher-performance front-end components. Short- to medium-range AESA radars with 500-1500 elements often use these to achieve the required system performance. GaAs and GaN technologies are often used for higher-performance front-end components, due to their higher power density, higher breakdown, and higher efficiency compared to silicon. GaAs is commonly preferred for PAs below 2 W, and GaN is often preferred for power levels 5 W and above. GaAs is commonly used for the LNA. GaAs or SOI are commonly used for the T/R switch. Multi-chip modules (or T/R modules) containing several die with different technologies can be used but require more complex and often more expensive manufacturing processes. A single MMIC die can be used with the same technology to integrate all three functions in a cost-effective QFN package.

The key specifications of the PA are output power, efficiency (which is very important for power consumption and heat dissipation), bandwidth, input and output return loss, and ruggedness. Low- to medium-power PAs can be packaged in cost-effective, plastic QFN packages with a copper base for effective heat transfer. Higher-power PAs are often housed in an air-cavity copper-moly package or module. As mentioned above, GaAs is commonly used for PAs below 2 W, and GaN is most often used above 2 W. Radar PAs can be designed for low duty cycle, short-pulse applications where thermal management is less stringent. The PA designs for longer-pulse to CW applications must be able to withstand the heat dissipation with an acceptably low junction temperature for reliable operation over the expected lifetime of the hardware.

Altum RF has developed a family of PAs for AESA radar at X-band (8 to 12 GHz) and Ku-band (13.5 to 17.5 GHz) with saturated output power in the 0.5 W to 1 W range. These PAs are highly efficient and meet the thermal and ruggedness requirements for AESA radar applications. These PAs are fabricated using a high-performance, cost-effective GaAs pHEMT process and housed in a 4X4 mm² QFN plastic package. A standard pinout and package outline drawing is illustrated below in *Figure 2*. A performance summary of these PAs is listed below in *Table 1*.

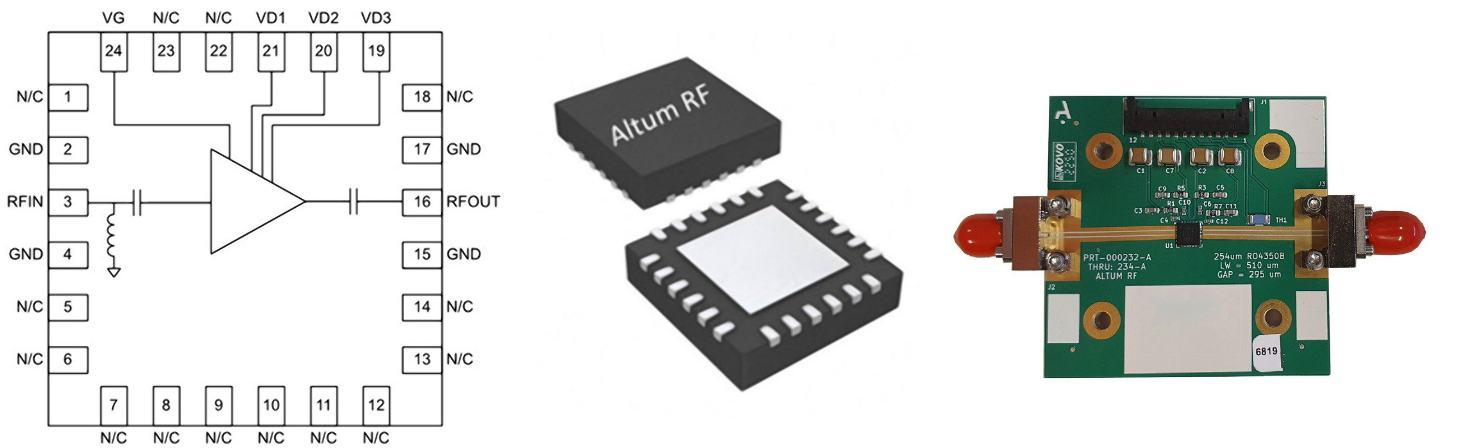

Figure 2: ARF1108Q4 Pinout, 24-Pin 4X4 mm² QFN Package, and Evaluation Board

Power Amplifier	Min. Freq (GHz)	Max. Freq (GHz)	Gain (dB)	P1dB (dBm)	PSAT (dBm)	PAE (%)	Vdd / Idq (V / mA)	Package
ARF1108Q4	8	12	20	27	27	32	8 / 110	4 × 4 QFN
ARF1109Q4	8	12	27	30	30	40	8 / 180	4 × 4 QFN
ARF1111Q4	13.5	18	22	27	28	35	8 / 100	4 × 4 QFN
ARF1112Q4	13.3	17	24	30	30	30	8 / 250	4 × 4 QFN

Table 1: Summary of X- and Ku-band PAs for AESA Radar Applications

Altum RF also offers LNA solutions for X- and Ku-band radar applications, as listed below in *Table 2*. These LNAs are broad-band and can be operated off a single 3 to 8 V supply. Both parts have excellent noise figure (NF) and are housed in small QFN packages. The LNAs have the lowest NF at 3 or 5 V but can be biased up to 8 V for higher P1dB for use as buffer or driver amplifiers while still maintaining low NF.

Low-Noise Amplifier	**Min Freq** (GHz)	**Max Freq** (GHz)	**Gain** (dB)	**NF** (dB)	**P1dB** (dBm)	**Vdd / Idq** (V / mA)	**Package**
ARF1211Q3	6	14	29	1.7	9	3 / 57	3 × 3 QFN
	6	14	28	1.9	17	5 / 60	
	6	14	26	2.0	20	8 / 64	
ARF1221Q2	6	18	24	1.0	12	5 / 23	2.5 × 2.5 QFN

Table 2: Summary of X- and Ku-band LNAs for AESA Radar Applications

Altum RF has the capability to quickly develop integrated X- and Ku-band front end ICs (FEICs) that contain the PA, LNA and T/R switch on the same GaAs pHEMT MMIC using existing and proven component designs. This FEIC would be a semi-custom product targeting the customer's specific requirements so this would require NRE or a minimum quantity purchase.

Conclusion

In order to detect and track smaller objects such as drones or UAVs, a different kind of radar is needed—different than the more traditional, military radars that are searching for larger objects such as aircraft or missiles. AESA radars are being developed for tracking smaller objects at shorter range using X-band and Ku-band frequencies. Off-the-shelf semiconductor components are now available to enable these applications, such as the digital signal processor/data converter, analog beamformer, and integrated front-end components. Key features of these components include the power levels, frequency bands, and compact size required to use these systems in urban areas.

References

1. The Continuing Evolution of Radar, From Rotating Dish to Digital Beamforming. (Microwave Journal, Jon Bentley and Jerome Patoux, Analog Devices, September 2022)
2. Tactical Expeditionary Radars, (Leonardo DRS)
3. Military Radar Market Size, Share & COVID-19 Impact Analysis, By Platform (Airborne Radar, Land Radar, and Naval Radar), By Range (Long, Medium, Short, and Very Short), By Application (Weapon Guidance, Airspace Monitoring & Traffic Management, Airborne Mapping, Ground Surveillance & Intruder Detection, Navigation, and Others), By Frequency (C-Band, S-Band, X-Band, L-Band, UHF/VHF, and Ku/K/Ka-Band), By Component (Transmitter, Antenna, Receiver, Duplexer, and Others), and Regional Forecast, 2021-2028, (Fortune Business Insights, January 2022)
4. Global AESA Radar Market Size, Share & Trends, COVID-19 Impact Analysis Report, By Type (Self-erecting AESA Radars, Flat Top AESA Radars, Hammerhead AESA Radars, and Luffing Jib AESA Radars), By Range (Very Long (> 500 km), Long (200-500 km), Medium (50-200 km), Short (10-50 Km), and Very Short (< 10 Km)), By Platform (Airborne, Land-Based, and Ship-Borne), and By Region (North America, Europe, Asia-Pacific, Latin America, Middle East, and Africa), Analysis and Forecast 2021 – 2030, (Spherical Insights, August 2022)

ALTUM RF

About Altum RF

Established by leading experts in the RF/microwave industry, Altum RF designs high-performance RF to millimeter-wave semiconductor solutions for next generation markets and applications. We work closely with our customers and partners to ensure superior technical support and customer service. With the help of our exceptional global partners, we can significantly shorten product development cycles by managing the entire supply chain from design to packaging, testing and qualification.

Altum RF develops a broad range of products for commercial and industrial applications, with strategic roadmaps to rapidly expand our product portfolio. Our engineers use decades of modeling expertise and system applications knowledge to define the right products for the most challenging requirements. Using proven technologies like GaAs or GaN, we are able to deliver optimal products in terms of RF performance, level of integration and cost. Whether your project is for Telecom, 5G, Satcom, RADAR Sensors, Test & Measurement, Aerospace & Defense or Industrial, Scientific and Medical (ISM) applications, discover Altum RF as your next RF semiconductor partner.

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