Technical White Paper

Enhanced Detections and Compute for ADAS systems with Next Gen Radar Sensors.

ABSTRACT

Texas Instrument's (TI's) next-generation radar sensors, AWR2E44P and AWR2944P, push TI's ADAS radar portfolio forward with a dedicated focus on performance improvements to meet stringent NCAP (new car assessment program) and FMVSS (Federal Motor Vehicle Safety Standards) automated driving and safety regulations. These radar devices bring a "Performance" extension to the AWR2944 platform, incorporating significant advancements in RF and computational capabilities that address the evolving needs of ADAS applications. Leveraging in-house optimized process technology, the AWR2E44P and AWR2944P are designed to enhance corner and front radar sensor functions by delivering better SNR, increased processing power, and larger memory capacity to cover United Nations Regulation No. 79 (UN R79) needs. These improvements extend detection range, improve angular accuracy, and enable more sophisticated processing algorithms for applications like tracking and classification. Additionally, it allows user to handle compute intensive AI/ML tasks, like radar perception, alongside signal processing algorithms.

TI's proprietary LoP (launch on package) technology, now in its second generation, further enhances RF performance, helping the devices maintain robustness across manufacturing variances while achieving advancements in cost-effectiveness. The easy-to-use HW evaluation module supported by software components enables faster development cycles. Maintaining backward compatibility with the previous generation, these new radar devices streamline the transition process, minimizing risk, saving development costs and reducing safety qualification timelines. This white paper underscores how AWR2E44P and AWR2944P radar sensors set a new benchmark in performance, offering OEMs a powerful and reliable device to meet future ADAS requirements and to advance autonomous driving capabilities with no compromise on SW reusability and scalability.

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1 Introduction

The automotive industry's shift toward higher autonomy levels demands radar sensors that meet stringent safety and performance criteria. Radar technology plays a critical role in providing real-time data for ADAS, supporting vehicle functions like ACC (adaptive cruise control), LCA (lane change assist), collision avoidance, etc. As vehicles evolve to meet increasing regulatory and consumer expectations, radar sensors must extend detection range, improve object discrimination resolution, and support robust data processing capabilities. AWR2E44P and AWR2944P sensors address these needs through key technical advancements in performance, computational capacity, and manufacturing quality, setting a new standard for high-performing, cost-efficient radar systems. AWR2E44P supports TI's LoP interface to antennas, whereas AWR2944P supports a PCB interface to antennas.

2 ADAS Radar Market Trends and Evolution of Requirements

Five to six years ago, the ADAS market required OEMs to provide NCAP BSD (blind spot detection), ACC (adaptive cruise control) and AEB (automatic emergency braking) in their vehicles, with detection ranges on the order of 150 to 200 meters. OEMs' architectures primarily relied on edge-sensing systems with CAN-FD interfaces with data rates limited up to 6-8 Mbps. Today, market trends have accelerated towards more stringent NCAP requirements with the introduction of UN R79: range requirements in corner and front radars have increased 30-40% and added capabilities like elevation detection are now requisite. OEMs' architectures have also transitioned to high-speed Ethernet interfaces, supporting data rates up to 100 Mbps or higher. The AWR2944 radar sensor was introduced to respond to these trends, providing enhanced configurations including four receive and four transmit channels. Looking to the future, radar sensors must meet even higher standards to support Level 3 and autonomous driving, including complex detection capabilities to differentiate static objects and improve object classification. These systems require an optimized SNR with an emphasis on reducing noise figure rather than solely increasing output power, as increasing solely output power comes with added thermal challenges and noise floor challenges if blockers or large objects are present in the scene. AWR2944P and AWR2E44P radar sensors leverage TI's proprietary enhanced process and second-generation LoP technology to achieve improved SNR and enhanced computational performance, supporting complex scenarios such as *eyes-off* and *hands-off* autonomous driving on highways and at intersections.

3 AWR2E44P and AWR2944P - Performance, Processing, and Memory Enhancements

The AWR2E44P and AWR2944P are performance enhanced relative to the AWR2944 product family, with enhancements to RF performance and compute capacity to meet NCAP and AD requirements. Figure 3-1 shows a block diagram of AWR2E44P/AWR2944P architecture. These devices are both single chip 76-81GHz FMCW radar sensor and include:

- 4 integrated transmitters
- 4 integrated receivers
- Calibration engines
- Monitoring engines
- Synthesizer
- C66x DSP
- Hardware security module (HSM)
- Hardware accelerator (HWA)
- Memory
- Interfaces

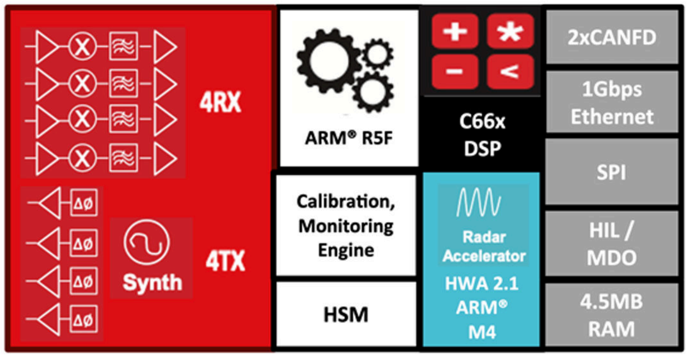


Figure 3-1. AWR2E44P / AWR2944P block diagram

AWR2E44P and AWR2944P offer an improvement in overall sensor SNR, enhanced compute capabilities, increased memory, uses TI second generation LoP, enables 10x higher data transfer rate, HSM improvement and eBOM (electronic bill of material) optimization.

3.1 Signal-to-Noise Ratio (SNR) Improvement

Through targeted transistor modifications in the LNA (low noise amplifier) and PA (power amplifier), the AWR2E44P and AWR2944P achieve a 2 to 3 dB gain in SNR. This improvement is crucial for high-accuracy detection and classification in complex driving environments. These targeted transistor enhancements improve F_t (transit frequency) and F_{max} (max oscillation frequency) of transistors. F_t is the frequency at which current gain approaches 1 or 0dB. Higher F_t supports faster clock speeds, essential for switching circuits, and improves noise figure, leading to enhanced front-end performance in mmWave applications. F_{max} is the frequency at which power gain approaches zero. Enhancing F_{max} improves transistor gain, significantly boosting power efficiency. With better F_t and F_{max}, TI is able to achieve better SNR without increasing the power consumption. Figure 3-2 shows how F_t and F_{max} are boosted on AWR2944P and AWR2E44P, up respectively +20% and +10% compared to AWR2944, which enables higher SNR. Figure 3-2 and Figure 3-4 shows enhancements achieved in output power and noise figure in AWR2944P at typical conditions. Thus, AWR2E44P and AWR2944P provide improved signal clarity, essential for accurate detection in high-noise environments with better SNR capabilities.

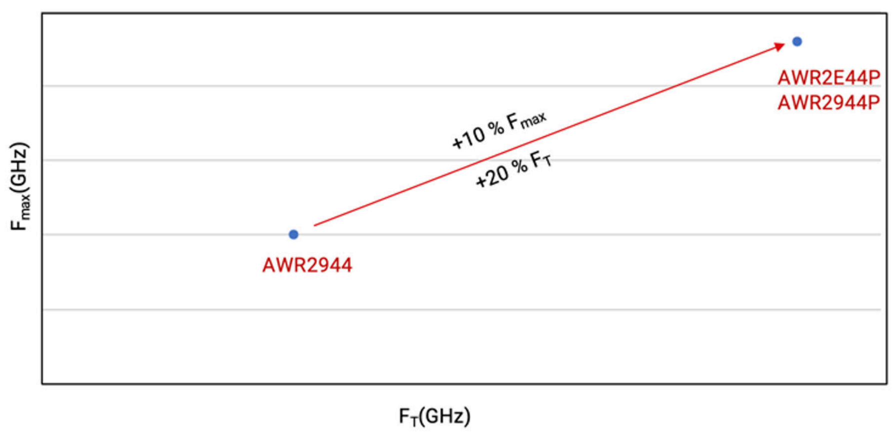


Figure 3-2. F_T and F_{max} enhancements on AWR2E44P and AWR2944P

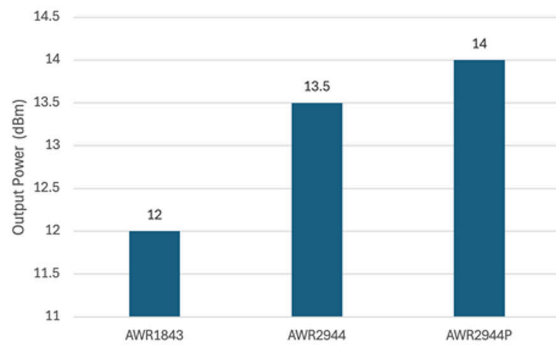


Figure 3-3. Output power enhancements on AWR2944P

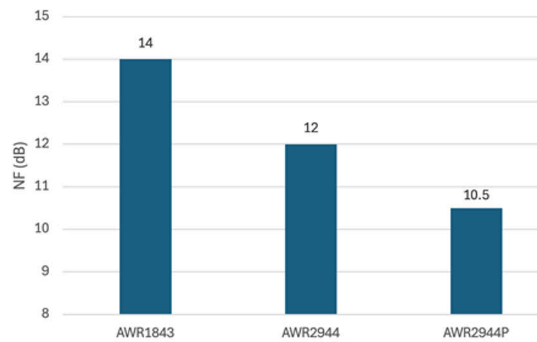


Figure 3-4. Noise figure enhancements on AWR2944P

3.2 TI 2nd Generation Launch on Package Technology (LOP)

TI's LoP technology enables direct signal transmission from the package radiating element to the 3D antenna through a waveguide within the PCB, thereby enabling efficient electromagnetic signal transfer. AWR2E44P uses second generation optimized transitions which reduce the transmission distance to antenna elements, improving the RF performance and thermal management. Figure 3-5 shows second generation LoP technology's use of double ridge waveguides (compared to oblong waveguides used in earlier generation). Double ridge waveguides enable approximately a 17% reduction in the transition size. This reduction is size enables improved board level reliability ensuring stable performance across PCB and antenna assembly variations. This more compact packaging also enables lower RF losses, and provides better spatial coverage by expanding the antenna's field of view (FOV), which is important for enhanced detection capabilities.

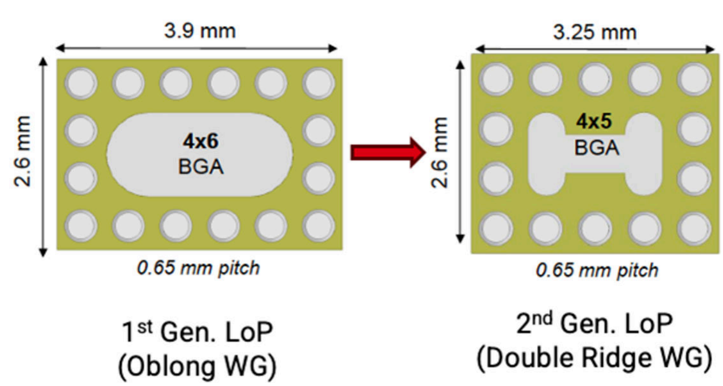


Figure 3-5. Enhancements in TI second generation technology

3.3 Increased Computational Capacity

AWR2E44P and AWR2944P, enable approximately 30% more processing compute. This is important to facilitate and improve complex post-processing algorithms, such as tracking, clustering, and classification, thereby providing advanced data for ADAS decision-making. This computing power allows these products to handle additional AI and ML tasks. Like radar perception, alongside signal processing algorithms. Compute enhancements on AWR2944P and AWR2E44P shows the compute enhancements done on AWR2944P and AWR2E44P relative to AWR2944.

Table 3-1. Compute enhancements on AWR2944P and AWR2E44P

	AWR2944	AWR2944P / AWR2E44P	AWR2944P – AWR2E44P Compute Enhancements
MCU	Arm® Cortex®-R5F, LS, 300MHz, 606 DMIPS	Arm® Cortex®-R5F, LS, 400MHz, 808 DMIPS	+50% DMIPS
		Arm® Cortex®-M4 100MHz, 125 DMIPS	
DSP	C66x, 360MHz, 11.52 GMAC	C66x, 450MHz, 14.4 GMAC	+25 % GMACS
HWA	HWA 2.1, 300MHz, 8.4GOPs	HWA 2.1, 400MHz, 11.2 GOPs	+33.33% GOPs

3.4 Expanded Memory for Radar Data Cube

AWR2944P and AWR2E44P have 20% more memory compared to the AWR2944. The allows for larger radar data storage and supports high-resolution data analysis.

3.5 1Gbps Ethernet Interface

With the increased SNR, numbers of objects detection will increase and higher Ethernet bandwidth provides increased data transfer capabilities. AWR2E44P and AWR2944P have dedicated Ethernet IP with 1 Gbps data rate which ensures seamless data communication across ADAS systems and meeting high-speed requirements for connected vehicle systems.

3.6 Enhanced Security and Reliability

The integrated Hardware Security Module (HSM) includes support advanced cryptographic algorithms such AES-256, SHA-512, PLA, TRNG, SM2/3/4 meeting increased data integrity and stringent cyber security requirements for autonomous applications.

3.7 eBOM Optimization

AWR2E44P and AWR2944P, provide a 25MHz clock output which can replace external crystal for Ethernet PHY chips, thereby optimizing the electronic bill of material (eBOM) of the radar sensor module.

4 No Compromise on SW Scalability and Reusability

Software is an integral part of the TI product offering. AWR2E44P and AWR2944P follows certification by TÜV SÜD as compliant to ISO 26262 and IEC 61508 for functional safety software development. To enable faster development cycles and reduce safety qualification times, AWR2E44P and AWR2944P are offered with reference code for customers to implement their customer applications with the following SW packages.

Most of the below software is provided through TI.com TI-REX (TI resource explorer) a one-stop shop for TI use case specific reference applications, SBL tools, detail documentation (TI Radar Academy) and training material.

4.1 Software Development Kit

AWR2E44P and AWR2944P comes with the *MCU Plus SDK*, which has SoC peripheral driver with application examples, SBL (secure boot loader) with UART, CAN, and ethernet support. To get started for faster development cycles an *OOB (out of box) demo* and *visualizer* can be used.

4.2 Microcontroller Abstraction Layer

For the quickest time to market, TI offers microcontroller abstraction layer (MCAL) which provides microcontroller drivers, memory drivers, communication and IO drivers with *example applications*. Figure 4-1 shows the AUTOSAR (**AUTO**motive **O**pen **S**ystem **Ar**chitecture) architecture with TI provided MCAL layer. Many TI-preferred partners including Vector integrates TI-MCAL with AUTOSAR® for Tier-1 SW releases.

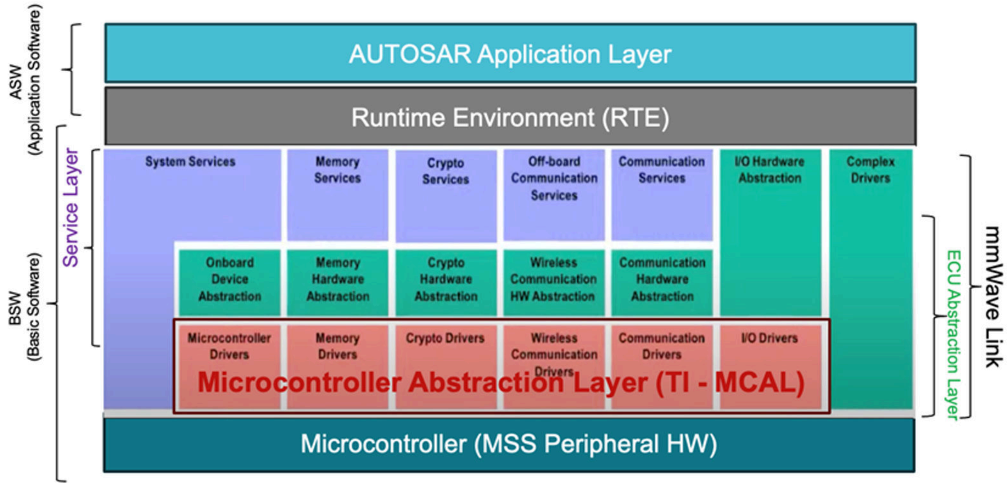


Figure 4-1. AUTOSAR architecture, with TI provided MCAL driver package

4.3 mmWave DFP (Device Firmware Package)

TI delivers a clean set of API's to control the AWR device's RF front end with extensive documentation in the ICD (interface control document) for TI mmWave DFP (device firmware package). The DFP enables quick migration form one AWR variant to another AWR hardware variant

4.4 TI Foundational Security

AWR2E44P and AWR2944P comes with the TIFS package that enables faster development of security features. Customers can use TIFS as a starting point for 3**rd** party HSM (hardware security module) SW development. Crypto accelerator drivers with examples and HSM runtime reference applications are provided in the TIFS package.

4.5 Safety Diagnostic Library

AWR2E44P and AWR2944P come with the TI SDL (safety diagnostic library) that enables easy implementation of safety diagnostic features and faster development of safety certification, with detail documentation in safety manual.

5 AWR2E44P Evaluation and Measurements

Easy-to-use evaluation module (EVM) is offered with AWR2E44P and AWR2944P devices, with direct connectivity to the DCA1000EVM for raw data capture. Figure 5-1 shows the AWR2E44PEVM with an installed 3D waveguide antenna. This EVM kit contains everything needed to start developing software for the on-chip C66x DSP, ARM® Cortex®-R5F controller, and hardware accelerator (HWA 2.1). There are several debug features that are included to assist in software development and hardware evaluation. These include on-board XDS110, CAN-FD transceiver, Ethernet PHY, temperature, current sensors, and high-speed connectors to interface with the DCA1000EVM or external debuggers. Figure 5-2 shows measured azimuth and elevation antenna pattern measurements on the AWR2E44PEVM.

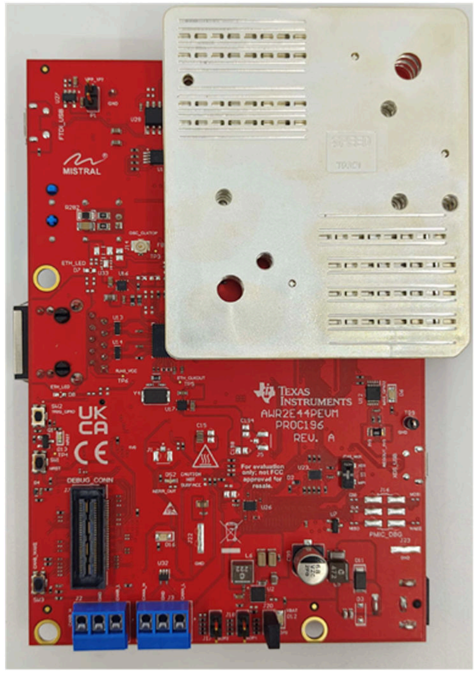
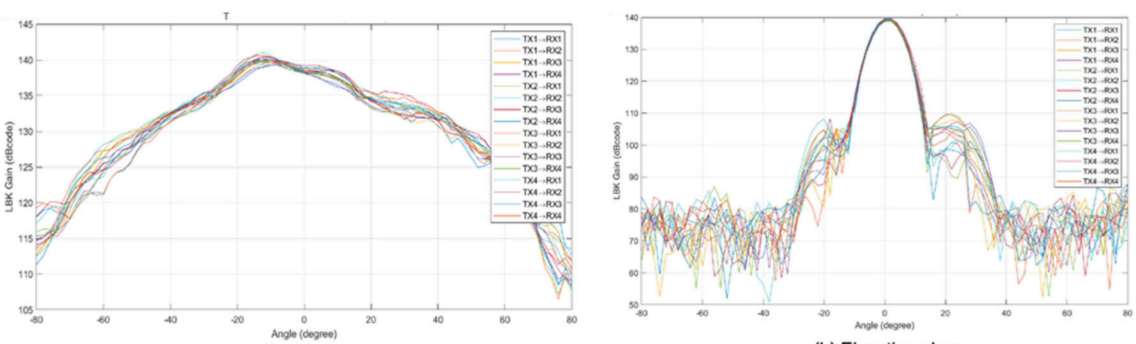


Figure 5-1. AWR2E44P evaluation module with 3D waveguide antenna



(a) Azimuth plane

(b) Elevation plane

Figure 5-2. AWR2E44P antenna measured results in azimuth and elevation planes

6 Summary

AWR2E44P and AWR2944P radar sensors represent a leap forward in ADAS radar technology, offering higher performance in detection range, angular accuracy, and computational capabilities. By utilizing proprietary process technology, including advanced transistor optimization and advanced second-generation LoP packaging, these devices address the automotive industry's evolving needs for higher accuracy and reliability in a cost-effective manner. Designed for hardware and software compatibility with previous models, these new radar sensors provide a seamless upgrade path, reducing OEM development costs and accelerating time to market. Through continuous innovation in hardware performance coupled with scalable and reusable software, TI is helping shape the future of ADAS and autonomous driving, creating safer, more responsive, and more intelligent vehicles.

7 Acknowledgments

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