A digital mmW radar IC for automotive use

Steve Taranovich - May 13, 2019

The company known as Uhnder is emerging from ‘stealth mode’ with their first chip and a paper they published at the ISSCC 2019, A 192-Virtual-Receiver 77/79GHz GMSK Code-Domain MIMO Radar System-on-Chip. Company co-founder Manju Hegde told me that they are planning a launch later in 2019.

Magna, a large automotive supplier that goes back to 1957, became their first customer very early on. Magna will deploy a next-gen, automotive-grade, mass-market sensor using the Uhnder digital radar on chip (RoC), leading to better automated and autonomous driving. See this video of Magna’s ICON radar for high-resolution automotive radar.

Their product is the first digital automotive radar (The military had digital radar earlier). Fred Harris worked on the military digital radar architecture for the Stealth Bomber several years ago. He is the co-inventor of the Blackman-Harris filter, and, as part of the extended Uhnder team, is lending his expertise. Their team took that military digital radar architecture and began the development of their automotive/commercial IC. Right now all the other automotive radars are analog modulated via FMCW.

The radar SoC

It’s just amazing to me what can be done with CMOS IC process technology today. Take a look at their IC block diagram in Figure 1.
Figure 1 The radar SoC block diagram, including the 12TX / 8×2 RX 77/79 GHz MIMO transceiver, digital signal processing, memory, and interfaces (Image courtesy of Reference 1)

Uhnder’s radar chip uses a phase modulated continuous waveform (PMCW)\textsuperscript{3,4}. This architecture features automotive radar in the 79 GHz band for medium (MRR) and short range radar (SRR), as well as the 76 Ghz to 77 Ghz for long range radar (LRR), also used by frequency-modulated continuous wave (FMCW) radar presently in use for automotive. The 79 GHz SRR can have a very wide bandwidth up to 4 GHz. Uhnder creates their PMCW architecture using a CMOS process.

With the advent of fast, low power, high speed ADCs developed in a CMOS process for 60 GHz communications, PMCW becomes an advantage because of the wide IF bandwidth that the CMOS ADC has, plus there are less IP and patents blocking access to the market for PMCW right now. An IEEE Radar Conference paper (Reference 4) concluded that, in a comparison of bi-phase PMCW and FMCW for 79 GHz automotive radar, PMCW was superior in performance and implementation.

One aspect of PMCW is that there is no range Doppler ambiguity with that architecture. The range response of the PMCW radar is thumbtack-like, meaning that both high range and Doppler resolution are achieved. Waveform generation of PMCW is very simple: the bi-phase modulation implementation is straightforward.

Uhnder started their design with interference-free codes for MIMO in code-domain, such as code-division multiple access (CDMA) has for communications. This is a robust detection method, with higher angular resolution, which enables distinct identification of two objects close together at some distance. They used the CDMA codes to modulate a carrier between 76 GHz and 81 GHz. With this digital code modulation (DCM) technique, they have several advantages over FMCW. One advantage is that for the analog portion of the chip, for the same number of channels, Uhnder has achieved an 8 to 10× smaller area than most competitors. Another advantage is that because they are coherent and use code domain diversity, with 12 transmit and 16 receive channels, they are able to get 192 virtual receivers (VRX), plus they are able to time-multiplex two sets of antennas to enable coverage of azimuth and elevation profiles.

Their design also enables the detection of interference from multiple other radar systems. The CDMA format allows for multiple transmitter/receivers not to interfere with each other. This is needed especially because moving into the 2022 to 2024 timeframe, there will be many, many cars with radar. Another key advantage of PMCW radar is that it uses a binary sequence, that allows for TX orthogonality by code/waveform design. This advantage is demonstrated in the paper in Reference 4 with a 4×4 PMCW MIMO radar that can detect two targets, with a radar cross-section (RCS) of 5 and 20 dBsm, at the same distance (same range bin) but at different angles with a high angular resolution.

And finally, they decided to go with a complete CMOS architecture with their IC. Low power is an obvious advantage with CMOS. The on-chip high speed ADC is quite complex, so CMOS is the best choice to keep the power dissipation of the IC low. The architecture also uses multiple transmitter/receivers which also benefit from the use of CMOS. The high bandwidth connectivity on the single monolithic chip gave the IC designers flexibility in locating where the memory would be placed, how much is needed due to high bandwidth, and other needs.

As for the system level, this is the highest resolution radar on the market. This is truly a 4-D radar system with four dimensions x,y,z (or polar co-ordinates) plus velocity. Also, because of the modulation used they can resolve large targets from small targets in close proximity; Uhnder claims that their angular resolution is better than anyone else has.
Two radar modes

This radar operates in two modes: MIMO mode where they transmit different codes to all the transmitters and they can receive those simultaneously in all the receivers. Since PMCW uses binary symbols, there is an advantage in MIMO radar that needs near-perfect orthogonal waveforms on the different TX antennas if they transmit signals simultaneously, which is needed for fast illumination of objects like in a driving scenario. The binary interference-free codes make orthogonality possible. They can also operate the chip in the phased array mode, where they digitally phase the transmitters to send the same code across the transmitters for phased array and beam steering.

There is a great deal of programmability on chip because they traded off analog simplicity for more processing power, allowing for increased flexibility. The company claims that this is the first software-defined radar. There are a great many features that can be configured in software and some very powerful DSPs on chip that customers can program if they wish in order to differentiate their product. This flexibility starts with the analog and goes all the way through to the software.

I can’t wait to see this radar in action in test cities in the near future. This architecture, coupled with V2X (see the related articles below to learn more) will make autonomous driving much more safe and reliable.

Steve Taranovich is a senior technical editor at EDN with 45 years of experience in the electronics industry.

References

2. PMCW-PMCW interference mitigation, United States patent number 9,772, 397 B1, Uhnder Inc, Sept. 26, 2017
5. Radar Basics, Radar Tutorial

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