Instrument technologies, instrumentation modulation/demodulation methods, Intelligent Transport System (ITS) sensors, network sensors

Takayuki INABA Laboratory

Takayuki INABA

Summary of Research

Development of Next-generation Automotive Radar

Our laboratory pursues research on instrument technologies and instrumentation systems for deployment in automotive radar and related applications.

Automotive Radar

Application of the most advanced instrument technologies to automotive radar can achieve various useful functions, including a preceding vehicle tracking, low-speed preceding vehicle tracking, collision damage reduction, and collision avoidance. Automotive radar equipped with these functions will serve as a key component of sensor systems used to achieve a safe intelligent transport system (ITS) society.

Instrument Technologies

One of the instrument technologies required to develop these functions is a modulation/demodulation technology for instrumentation. Our laboratory is developing the new modulation/demodulation method in which transmit sequence of the carrier frequency has a step-like form. The target distances are measured by using phase differences. Our laboratory is also creating integrated methods involving other different measuring principles. By using these methods, high range resolution is achieved by a narrowband receiver and a narrow transmit frequency bandwidth. Using the field of communications as an analogy, the effect is equivalent to increasing bit rates by several orders of magnitude without expanding the communication frequency bandwidth. The narrow transmit frequency bandwidth used by these modulation/demodulation methods can mitigate mutual interference, since each transmit frequency is limited to a narrow bandwidth. Furthermore the interference at the same bandwidth also can be avoided by using inter-pulse code modulation.

Instrumentation Systems

To develop a new instrumentation system, it is required to design sophisticated transmit waveforms and signal processing algorithms for received waveforms to ensure high interference resistance and satisfy requirements for the covered area, accuracy, resolution, and data rate.

By law, automotive millimeter-wave radar is restricted to a bandwidth of 1 GHz and transmission power of 10 mW at a transmit frequency of 76.5 GHz. Proper design of the modulation/demodulation method for a single radar unit is required to cover both long and short range. These instrument technologies will also find applications in various other fields beyond automotive radar.

Our laboratory plans to apply the technologies to the radar altimeter to be mounted on the SELENE 2 lunar lander of the Japan Aerospace Exploration Agency (JAXA) and the ATC secondary radar of the Electronic Navigation Research Institute (ENRI).

The Frequency Modulated Continuous Wave (FMCW) system currently employed by long-range automotive radar units may cause various problems when automotive radar becomes standard equipment in many vehicles in the future, including mutual interference and detection errors. Additionally, higher resolution must be achieved to alleviate collision damage.

When seeking to improve interference resistance and increase the range resolution, researchers tend to use pulse compression (spread spectrum method, equivalent to the Code Division Multiple Access (CDMA) system used by mobile phones for wireless communications). However, since pulse compression measures distance based on the round-trip propagation time of transmitted pulse, it requires a wideband receiver, high-speed A/D, and high-speed signal processor. All these requirements increase costs.

Keywords

Automotive radar, ITS, pulse compression, step frequency, UWB, FMCW, super-resolution method, DBF, array antenna, multistatic radar, bistatic radar, MIMO radar, multi-sensor technology

Affiliations	Institute of Electronics, Information and Communication Engineers; Institute of Electrical and Electronics Engineers (IEEE)
Member	Takayuki Inaba, Professor

Advantages

Capacity to Provide Optimal Technologies Drawing on Extensive Experience with Concept/system Design-based Manufacture

Automotive radar is expected to diffuse rapidly during the next five to ten years, in the same way as mobile phones have. Aside from our laboratory, no university laboratories are engaged in the research in this field. Our laboratory has a great advantage compared to the other research groups, since we have worked on this field over years.

Having held a post at a company manufacturing plant, Professor Inaba has many years of experience with manufacturing. He has handled a wide range of tasks, ranging from research and development to the technical marketing of instrumentation systems of various types, including advanced military radar systems and the automotive millimeter-wave radar currently being explored.

In joint research with corporations, our laboratory focuses on (1) a customer-needs-oriented policy and (2) concept/system design-based manufacturing.

With respect to (1), we identify the customer's needs and determine what needs to be done to meet the customer's needs. Alongside our research partners, we then examine which technologies are best-suited for achieving the goals. Rather than resorting to existing research results, we proceed based on our sense that the manufacturing operations required by Japanese industry will grow increasingly complex and diverse. Meeting these needs will require not just the development of individual element technologies in areas such as circuit design. The designs created at the conceptual stages have major effects on whether a project succeeds or fails, as well as on cost competitiveness.

With regard to (2), we place a high priority on concept/system design at all times. We conduct benchmark tests, select highlight features of our developments, and perform simulations and detailed technical feasibility studies before starting the design process. Drawing on his experience of working outside academia, Professor Inaba continues to engage in joint research projects.

Future Prospects

Taking Automotive Radar to a New Stage of Evolution and Incorporating it into Other Measurement Devices and Security Systems

We are continuing research on automotive radar as part of efforts to contribute to the diffusion of this technology.

At this point, automotive radar is in its early developmental stages, comparable to first-generation mobile communications. Mobile communications began with analog FDMA, then eventually advanced to the CDMA, the third generation, and then to the WiMAX Orthogonal Frequency Division Multiplexing (OFDM) system currently in use. Radar is expected to follow a similar growth path: Radar must be multi-functional, provide high performance, and integrate with other sensors. We are striving to create the best systems to meet different individual needs.

Instrument technologies are widely used in various social situations.

Instrument technologies have clear applications in the areas of safety/security enhancement systems (e.g., railway radar, railway crossing surveillance radar, traffic flow measurement sensors, sensors for detecting people falling from train station platforms, safety monitors for mechanical parking facilities, safety monitors for inside buses and areas surrounding buses, intruder detection sensors for important facilities); countermeasures for aging social structures (e.g., nondestructive inspections of buildings, bridges, and plants; nondestructive inspection radar for termite detection); medical equipment (e.g., contactless respiration/heartbeat measurement instruments); and equipment with high social demand (e.g., wide-area disaster survivor search radar).

In all these applications, millimeter-wave radar and microwave radar incorporating advanced measurement technologies will work very well, since radar has the following features. Radar can measure the velocity directly and has a wide detection area, long detection range, and high detection performance at all hours of the day and night. Furthermore it can work even under unfavorable conditions such as rain, fog, glare, even when covered in mud.

We also plan to integrate control and radar technologies and be engaged in research and development related to autonomous self-driving cars (robot cars) ideally suited to future society.

Professor Inaba has been active in research on the Digital Beam Forming (DBF) antenna technologies for many years. We intend to expand this technology and apply it to develop networked multi-sensor technologies (Multi-Input Multi-Output (MIMO) radar for signal-level fusion, not information-level fusion) for various applications.

Automotive radar

Railway safety monitoring system


Stepped multiple-frequency CPC (Complementary Phase Code) millimeter-wave radar