Sub-Carrier Successive-Approximation Mm-Wave Radar For High-Resolution 3D Imaging

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SUMMARY

UCLA researchers in the Department of Electrical Engineering have developed a sub-carrier successive approximation radar (SAR) system with a sufficiently high accuracy to capture three-dimensional images of objects concealed either under the clothing of a person, or within small packages.

BACKGROUND

Radar based automotive and object detection systems have gained increasing attention in recent years. Adding to this interest are applications that employ millimeter-wave radar techniques to construct short-range three-dimensional (3D) imaging for security screening and biomedical applications. These types of millimeter-wave imagers have only been demonstrated using III-V technology, as complementary metal oxide semiconductor (CMOS)-based radars suffer several range, resolution and accuracy limitations due to limited output power and linearity.

Most CMOS millimeter wave radar systems used in automotive applications are based on frequency-modulated continuous wave (FMCW) technique, which is excellent for accurate ranging. However, range resolution and accuracy in a FMCW system are limited by sweep generator linearity, front-end linearity, and the available resolution bandwidth to process intermediate frequency signal to and from the target. Implementation of FMCW becomes particularly difficult for 3D millimeter-wave imaging when high operating frequency is critical, as the attainable spatial resolution is fundamentally limited by the wavelength of the imaging system. Therefore, a need exists for millimeter-wave short-range 3D imaging systems to overcome the limitations of FMCW.

INNOVATION

Researchers at UCLA have constructed a sub-carrier successive approximation radar (SAR) system with a sufficiently high accuracy to capture 3D images of objects concealed either under the clothing of a person, or within small packages. The described radar system operates based on successive phase approximation of the time-of-flight at different sub-carrier (intermediate) frequencies, meaning the radar directly measures the round trip time by estimating the phase delay of the carrier. This overcomes the intrinsic range ambiguity faced by phase-based radars when the target travels beyond one wavelength of the carrier. With this radar system, the frequency of the carrier does not need to be swept as in conventional radars, thereby relaxing RF front-end bandwidth and linearity requirements. The accuracy is determined by the number of successive approximations performed and the period over which the output radar signal is integrated. Therefore, any level of desired accuracy may be achieved while only being limited by the extent of system noise.

APPLICATIONS

The described radar system can be implemented with a wide range of device technologies, including but not limited to Si CMOS, Si BiCMOS, HBT, HEMT or PHEMT, depending on the frequency, required accuracy, and target distance of the 3D imaging applications in security screening, aerospace and automotive navigation.

ADVANTAGES

- Much higher resolution due to the high operating frequencies
- Phase based radar is narrowband and has far more relaxed requirements on the transmitter and receiver

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OTHER INFORMATION

KEYWORDS

Radar imaging, imaging, millimeter-wave imaging, three-dimensional display, CMOS integrated circuits, sub-carrier successive approximation radar, sub-carrier SAR phase radar, automotive navigation, aerospace navigation, object detection, millimeter-wave 3

CATEGORIZED AS

- **Communications**
  - Wireless
- **Imaging**
  - 3D/Immersive
  - Security
- **Security and Defense**
  - Screening/Imaging
- **Transportation**
  - Aerospace
  - Automotive

RELATED CASES

2012-102-0

- Any level of desired accuracy can potentially be achieved by integrating output radar signal for longer periods of time
- Conduction of successive ranging measurements at increasing intermediate frequencies allows for range detection without distance ambiguity

STATE OF DEVELOPMENT

A prototype has been constructed using a 65 nm CMOS process and successfully demonstrated at both 144 and 155 GHz with better than 1 cm of resolution at 1 m of target distance.

PATENT STATUS

Country	Type	Number	Dated	Case
United States Of America	Issued Patent	9,341,710	05/17/2016	2012-102

RELATED MATERIALS

- Tang, A., Virbila, G., Murphy, D., Hsiao, F., Wang, Y.H., Gu, Q.J., Xu, Z., Wu, Y., Zhu, M. and Chang, M.C.F., 2012, February. A 144GHz 0.76 cm-resolution sub-carrier SAR phase radar for 3D imaging in 65nm CMOS. In 2012 IEEE International Solid-State Circuits Conference (pp. 264-266). IEEE.
- A. Tang, G. Virbila, H. Wu, M.F. Chang "A 155 GHz 220mW Synthesizer-Free Phase Based Radar System in 65nm CMOS Technology", IEEE International Microwave Symposium 2013.

ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- Grouping Algorithm For Touchscreen Finger Position Detection

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