World Academy of Science, Engineering and Technology
International Journal of Information and Communication Engineering
Vol:16, No:10, 2022

A Carrier Phase High Precision Ranging Theory Based on Frequency Hopping

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Abstract : Previous indoor ranging or localization systems achieving high accuracy time of flight (ToF) estimation relied on two key points. One is to do strict time and frequency synchronization between the transmitter and receiver to eliminate equipment asynchronous errors such as carrier frequency offset (CFO), but this is difficult to achieve in a practical communication system. The other one is to extend the total bandwidth of the communication because the accuracy of ToF estimation is proportional to the bandwidth, and the larger the total bandwidth, the higher the accuracy of ToF estimation obtained. For example, ultra-wideband (UWB) technology is implemented based on this theory, but high precision ToF estimation is difficult to achieve in common WiFi or Bluetooth systems with lower bandwidth compared to UWB. Therefore, it is meaningful to study how to achieve high-precision ranging with lower bandwidth when the transmitter and receiver are asynchronous. To tackle the above problems, we propose a two-way channel error elimination theory and a frequency hopping-based carrier phase ranging algorithm to achieve high accuracy ranging under asynchronous conditions. The two-way channel error elimination theory uses the symmetry property of the two-way channel to solve the asynchronous phase error caused by the asynchronous transmitter and receiver, and we also study the effect of the two-way channel generation time difference on the phase according to the characteristics of different hardware devices. The frequency hopping-based carrier phase ranging algorithm uses frequency hopping to extend the equivalent bandwidth and incorporates a carrier phase ranging algorithm with multipath resolution to achieve a ranging accuracy comparable to that of UWB at 400 MHz bandwidth in the typical 80 MHz bandwidth of commercial WiFi. Finally, to verify the validity of the algorithm, we implement this theory using a software radio platform, and the actual experimental results show that the method proposed in this paper has a median ranging error of 5.4 cm in the 5 m range, 7 cm in the 10 m range, and 10.8 cm in the 20 m range for a total bandwidth of 80 MHz.

Keywords : frequency hopping, phase error elimination, carrier phase, ranging
Conference Title : ICT 2022 : International Conference on Telecommunications
Conference Location : Beijing, China
Conference Dates : October 06-07, 2022