博士論文（要約）

Performance improvement in ultra wideband (UWB)
systems under narrowband interference
（狭帯域干渉下での超広帯域（UWB）システムの
性能向上に関する研究）

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In recent years, Global Positioning System (GPS) receivers have been used for devices for the consumer market and location recognition is widely spreading in public. However, although GPS functions normally in open spaces, the accuracy is limited to a few tens of meters to hundreds of meters and is far lower than the achievable precision in complex environments (such as building interior and urban canyons). In many cases, the GPS signal is too weak to enter buildings, and obstacles cause severe multipath propagation when there are walls, it is very difficult to accurately estimate the time of arrival (TOA) of the direct route. Even if the GPS functions in the same way as the open space environment, it is not enough for many indoor positioning applications that require precision that is at least an order of magnitude higher than the accuracy that the current GPS can provide. Ultra wideband (UWB) technology is drawing attention as an ideal candidate for providing location information in such complicated environments. By using very short time-domain pulses with a bandwidth of several GHz, time resolution becomes high and performance is improved in the TOA measurement.

Although UWB technology has very promising features in location recognition, there are still some challenges that need to be overcome. Multipath, interference with other communication and characteristics of the antenna itself to be used are the typical problems in UWB systems.

In this research, we focused on narrowband interference and dispersion characteristics of antennas. For UWB which spreads over a wide band and has small spectral density, narrow band communication with high spectral density adversely affects. Also, the antenna itself used for communication is required to have stable performance over a wide band.

For the narrowband interference, we proposed a new interference reduction method using the frequency dependence of the array antenna. We take advantage of the frequency characteristic of array antennas to realize NBI mitigation by steering nulls only toward the direction of interference adaptively. It is an expansion of the idea of power inversion adaptive array (PIAA) to the use in UWB systems. PIAA points nulls of the array to the direction of large-power signal. Since desired wave and interference wave is distinguished only by input power, PIAA does not require a priori knowledge about signal structures or arrival angles.

Our method can suppress NBI without learning. When a desired signal is a sequence of UWB pulses and interference is narrowband, the spectrum density of the pulses is much smaller than that of the interference. By taking advantage of this characteristic, we can turn nulls to the NBI(s) to mitigate interference effectively. This NBI mitigation method does not need iteration such as feedback loop, and thus requires only a small amount of calculation.

The results showed that the binary data of the desired signal is restored. This method does not need a priori knowledge about interference waves. It can cope with variously directional and multiple-frequency interference waves without rigorous adjustment of the element number in the array antenna.

Next, we adopt NBI mitigation method to a null steering DoA estimation method using a complex-valued spatio-temporal neural network (CVSTNN) for UWB imaging and adopted to UWB ultrasonic array system. For acoustic imaging with a high resolution in the range direction (direction of propagation), the pulse should be short. A short pulse has a wide frequency band, which is also favorable for avoidance of target breaking through acoustic resonance. However, because of the wide bandwidth, the conventional delay-and-sum (DAS) method fails. CVSTNN scheme realizes a practical-resolution imaging in the azimuth direction (direction perpendicular to the range direction) even with a small-aperture array. Simulations demonstrate that the proposed method presents a higher accuracy than conventional CVSN based DoA estimation method under interference.

Then, in order to realize stable performance in wide band antennas, a new shaped tapered slot antenna (TSA) is proposed and fabricated, and its dispersion characteristics were confirmed. TSA is a widely used relatively wideband antenna. TSAs are end-fire traveling wave antennas and have infinite bandwidth in theory. However, the operational bandwidth is limited in practical use. The lower-limit frequency depends on the aperture size, i.e., the end-to-end width of the pair of fins. we propose a compact folded-fin TSA with a wide radiation band. The curved fins and a large aperture realize less reflection and constant group delay. However, a large aperture makes antenna bigger. In this section, we propose a folded fin structure that leads to a TSA having both small size and low lower-limit workable bandwidth. This structure has not been proposed in the TSA field before. We evaluate the reflection and group delay in simulation and experiments. We find that the new structure realizes a 3.1 GHz lower limit in simulation with a compact size of 40mm antenna width, the smallest size which has ever been reported. Experimental results are also shown and discussed.