RESEARCH ON NEAR FIELD PASSIVE LOCALIZATION BASED ON PHASE MEASUREMENT TECHNOLOGY BY TWO TIMES FREQUENCY DIFFERENCE

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Abstract: A new method to near field passive localization based on phase shift measurement technology by frequency difference is presented in this paper. Near field passive localization accurately is a difficult problem all the while, especially for a special distance range (neither long nor short). In terms of physics ultrasonic localization technology cannot be used to near field passive localization because of its sharp attenuation, so electromagnetic wave is the sole choice. TDOA (Time Difference of Arrival) method is of no effect since time difference of arrival signal can not be measured accurately with conventional method on the condition of near field by reason of electromagnetic wave's velocity which is same as light velocity. It is also difficult for only using traditional DOA (Direction of Arrival) method to locate an object quickly and accurately under the same condition for the same reason. The method on phase measurement technology by two times frequency difference can solve the question perfectly .The principal interpretation ,measurement result and error analysis of phase shift measurement technology by frequency difference is presented in this paper.

Keyword: two times frequency difference, near field localization, phase shift measurement electromagnetic wave.

Introduction: *Distance measurement is a traditional problem. For non contact measurement there are two medias——ultrasonic and electromagnetic wave that we can choose to realize it. Ultrasonic is a kind of mechanical wave so that it attenuates quickly when propagating in air. Generally ultrasonic can measure distance less than 30 meters in air. Certainly there is another reason that real time measurement is impossible to achieve: for a moving object we can not measure the accurate position real time because its position has changed during the propagating time .Comparing to ultrasonic electromagnetic wave can measure very long distance such as military radar do, however since electromagnetic wave propagates as quickly as velocity of light* $3\times10^8 m/s$ *, there will be a prodigious absolute error for measuring a distance directly with the time difference of arrival signal when the distance to be measured is not very long (<200m).Thus for a special distance (50m—200m) neither ultrasonic nor electromagnetic wave is fit to measure it with the conventional method. A new method to near field passive localization based on phase shift measurement technology by two times frequency difference is presented in this paper to solve the problem perfectly. It is easy to locate an object through triangle method if the distance to two fixed receive ports are obtained separately so only the distance measurement is discussed in the paper .*

Results: **1 Distance measurement principal by measuring phase shift**

Distance measurement by phase shift is implemented by amplitude modulation electromagnetic signal. Assuming that the carrier frequency is f , the modulation waveform is showed in Figure 1, then the wavelength $\lambda = c/f$, c——velocity of light. If signal propagates from A to B , phase shift is presented as

$$\phi = 2m\pi + \Delta\phi = 2\pi(m + \Delta m) , \quad (1)$$

Where m =0, 1, 2, … $\Delta m = \Delta\phi / 2\pi$

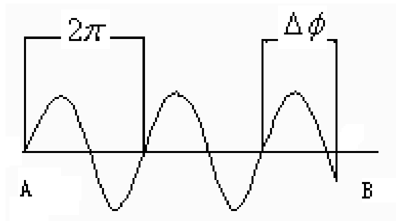

Figure 1. the waveform of signal

If the time for signal propagating from A to B is t, distance between A to B can be presented

$$L = ct = \lambda(m + \Delta m) \tag{2}$$

So if only the integral multiple m of period 2π and the residual Δm in phase shift is measured, the distance can be obtained through the upper equation. Thus the electromagnetic wave wavelength λ can be seemed as a "ruler".

Phase shift measurement technology can only measure the residual phase $\Delta\phi$, this is to say the residual $\Delta m = \Delta\phi / 2\pi$ can be obtained, but the integral multiple m of phase period 2π cannot be determined. So when the distance measured is long than wavelength the measurement is not accurate, only when the distance measured is short than wavelength the measurement is accurate and the result is showed

$$L = \frac{\lambda \cdot \Delta\phi}{2\pi} \tag{3}$$

If the distance measured is long comparatively ,the modulation frequency can be depressed so as to make $L < L_s$, thus L can be calculated accurately.

2. Electromagnetic wave phase detect technique

(1) direct detection ruler frequency

The detection ruler frequency $f_s = c / L_s$ can derive from the detection ruler L_S, f_s is corresponding to detection ruler length directly, namely the detection ruler length is determined by detection ruler frequency. This method is named as the direct detection ruler frequency mode.

(2) indirect detection ruler frequency

In practice the distance to be measured is great generally so indirect detecton ruler frequency mode is adopted. Two modulation frequencies f_{s1} and f_{s2} are used to measure the same distance L

$$\begin{cases} L = L_{s1}(m_1 + \Delta m_1) \\ L = L_{s2}(m_2 + \Delta m_2) \end{cases} \tag{4}$$

The first equation multiply through on both sides by f_{s2} and the second equation multiply through on both sides by f_{s1}, then subtract the first equation from the second equation through on both sides and the formula converts to

$$L = \frac{L_{s1}L_{s2}}{L_{s1} - L_{s2}}[(m1 - m2) + (\Delta m1 - \Delta m2)] = L_s(m + \Delta m) \tag{5}$$

Where $$L_s = \frac{L_{s1}L_{s2}}{L_{s1}-L_{s2}} = \frac{c}{f_{s1}-f_{s2}} = \frac{c}{f_s}$$

(6)

$$f_s = f_{s1} - f_{s2},\ m = m_1 - m_2,\ \Delta m = \Delta m_1 - \Delta m_2 = {(\Delta\phi_1 - \Delta\phi_2)}/{2\pi}$$

Here L_S is a new detection ruler and f_s is the new detection ruler frequency according to L_S. $\Delta\phi_1$ and $\Delta\phi_2$ are the phase mantissa which are measured separately when measuring the same distance with f_{s1} and f_{s2} separately ; the difference $\Delta\phi_1 - \Delta\phi_2$ is equal to $\Delta\phi$ that is the phase mantissa when measuring the same distance directly with a single frequency $f_s = f_{s1} - f_{s2}$.This is the basic principal of indirect detect ion ruler frequency method.

(3) phase detect principal by frequency difference in active distance measurement

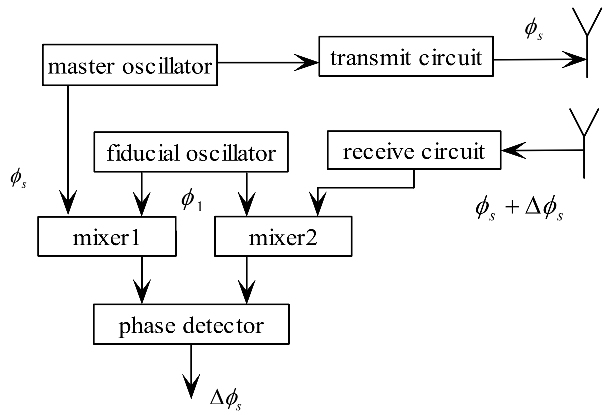

Figure 2.Principal graph of phase detect by frequency difference

Generally the active distance measuring instrument by phase shift is adopting technology of phase detect principal by frequency difference .The principal of phase detect by frequency difference is showed in Figure 2. The signal generating from the master oscillator is modulated and sent out through transmit circuit , it backtracks to the receive circuit after reflecting by the target through $2L$ distance. The original signal and the receiving signal are presented as the following two equations

$$e_{s1} = A\cos(\omega_s \cdot t + \phi_s)$$

(7)

$$e_{s2} = B\cos(\omega_s \cdot t + \phi_s + \Delta\phi)$$

(8)

Where $\Delta\phi$ denotes phase shift, assuming the signal generated from the fiducial oscillator is :

$$e_1 = C\cos(\omega_1 \cdot t + \phi_1)$$

(9)

The signal e_1 is mixing with e_{s1} and e_{s2} in mixer 1 and mixer 2 separately, then the output reference signal e_r and distance measurement signal e_s are obtained from the two mixers ; they are presented as:

$$e_r = D\cos[(\omega_s - \omega_1)\cdot t + (\phi_s - \phi_1)]$$

(10)

$$e_s = E\cos[(\omega_s - \omega_1)\cdot t + (\phi_s - \phi_1) + \Delta\phi] \quad (11)$$

Thus we can measure the phase difference $\Delta\phi$ of the two mixing signals through phase detector. A conclusion that the phase difference obtained by two low frequency signals e_r and e_s is equal to the phase difference obtained directly by the high frequency is drawn.

Certainly the distance information is preserved because the distance is corresponding to phase difference wholly. But to low frequency signal the period is long comparatively so that the same phase occupies more time so as to increase the measurement precision, therefore the distance measurement precision is also increasing, nevertheless this method does not solve the measurement range problem. To solve this problem we proposed phase shift measurement technology by frequency difference.

(4)phase shift measurement technology by two times frequency difference

For a special distance (neither long nor short, for example 50-200 meters), range and precision is the two factors that are needed to consider when choosing the measurement frequency, now we will explain the relation between range and frequency through an example. Assuming the maximum distance is 200 meters the wavelength should be $\lambda \geq 200$ meters, now we choose $\lambda = 200m$ ($f = 1.5MHz$). Generally the transmit antenna should be longer than 1/10 wavelength of the electromagnetic wave at least, half wavelength antenna is in common use in engineering, hence, it is impossible to use an antenna 100 meters long apparently. To solve the contradiction we choose two signals which frequency difference is $1.5MHz$ (for example $f_{s1} = 150MHz$ and $f_{s2} = 148.5MHz$)to measure it simultaneously, and it is feasible in practice, their phase difference is equal to the result derived of the measurement with $1.5MHz$ signal directly.

Now another question is of emergence□how to use two signals to measure the same distance at the same time? I.e. how to avoid the mutual interference? If the target object is stationary the question is simple, at first the first signal f_{s1} is transmitted and then the second signal f_{s2} is transmitted after a fixed delay time Δt. If the target object is moving we still can transmit signals as the process above on the condition that the object position changed hardly during the fixed delay time Δt .Usually the position shift is *mm* level if Δt is *ms* level , this is to say if the measurement precision is not greatly high the method is feasible.

Figure 3 and figure 4 are the principal graphs of phase detect by two times frequency difference when the signal frequency are ω_{s1} and ω_{s2} separately. In a practical system receive circuit 1 and 2 □four mixers and phase detector can be in common use, only four fiducial oscillators are of independence. It is important to explain that the graph above is dead against the passive distance measurement (the transmit circuit is separate from the receive circuit in electronic, i.e. there is a separate signal transmit source, the receive circuit receives the signal arriving directly (no reflecting)) so that only the receive parts are showed .To comprehend the principal graph better you can seem the receive circuit 1 in figure 3 as the master oscillator in figure 1.In addition there are four mixers (two mixers in figure 1) in figure 3 , thus it can improve the phase measurement precision. In figure 3 the result (frequency and phase) of every step is showed, $\Delta\phi_{s1}$ and $\Delta\phi_{s2}$ are obtained from figure 3 and figure 4. $\Delta\phi = \Delta\phi_{s1} - \Delta\phi_{s2}$ is the phase shift when we measure the distance with the frequency $f_s = f_{s1} - f_{s2}$ directly . Therefore the distance can be calculated with formula (3).

Now it is necessary to interpret the meaning of two times frequency difference, the process in Figure 3 or Figure 4 is an integral process of the first frequency difference. Figure 3 and Figure 4 are combined into one system, $\Delta\phi = \Delta\phi_{s1} - \Delta\phi_{s2}$ is obtained by the second frequency difference ($f_{s1} - f_{s2}$)

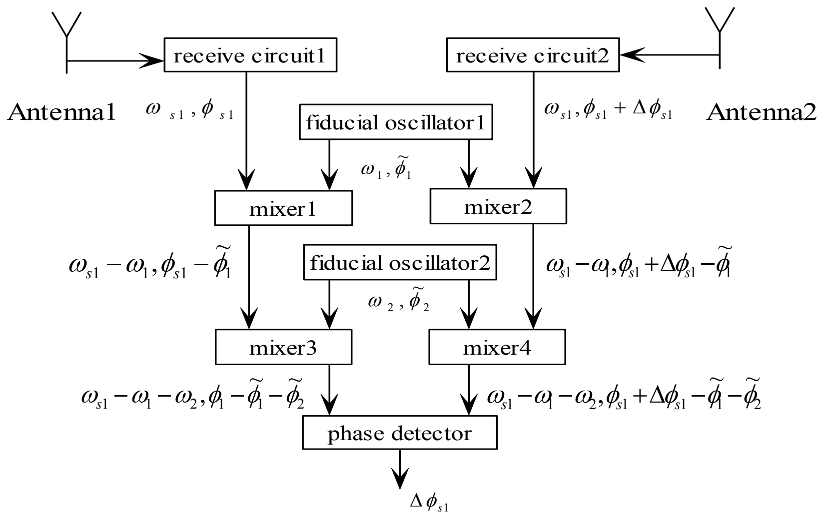

Figure 3. Principal graph of phase detect by two times frequence difference when the signal frequence is ω_{s1}

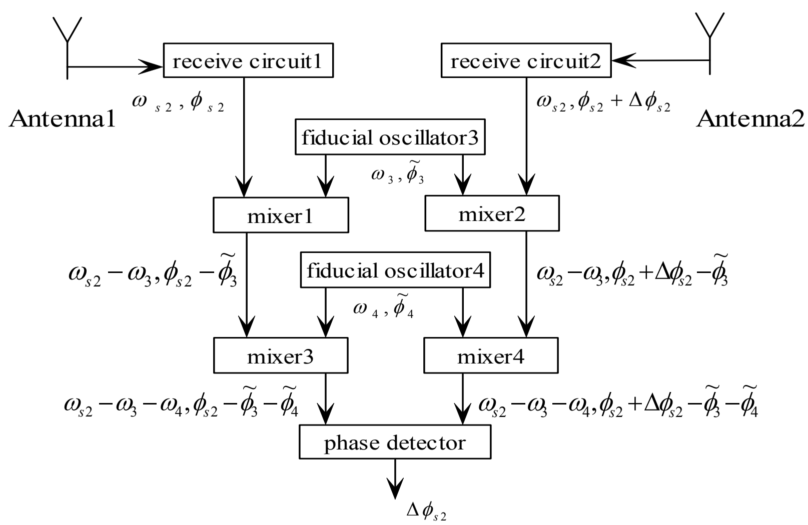

Figure 4.Principal graph of phase detect by two times frequence difference when the signal frequence is ω_{s2}

Discussion□Now let's see an examples, if the maximum distance is 200 m , then $f_S = 1.5MHz$, assuming $f_{S1} = 150MHz$ and $f_{S2} = 148.5MHz$, designed frequency of ω_1 □ ω_2 □ ω_3 and ω_4 are 145MHz□143.5 MHz □4.998 MHz □4.998 MHz , the distance to be measured is 105m , then $\Delta\phi_1 = 0.5\times 2\pi$ and $\Delta\phi_2 = 0.975\times 2\pi$ are obtained from figure 3 and figure 4, $\Delta\phi = (1.5-0.975)\times 2\pi = 0.525\times 2\pi$ (if $\Delta\phi_1 < \Delta\phi_2$ then $\Delta\phi_1 = \Delta\phi_1 + 1$ because $\lambda_1 < \lambda_2$), so the result measured is $L = 0.525\times 200 = 105m$.

Certainly it is only an ideal situation, it will generate error in a practical situation .At present the absolute error is 0.5~1 meters in this system. The measurement precision is concerned with plenty of factors, in this paper the influence of fiducially oscillator's frequency value and precision □clock precision and the consistency of mixers and phase detector are analyzed.

1. Frequency Value and precision of fiducial oscillator determined the precision of phase shift value $\Delta\phi_1$ and $\Delta\phi_2$, for example if the second level fiducial oscillator frequency is 4.8 MHz then the final frequency is $150-145-4.8 = 0.2MHz$, if the second level fiducial oscillator

frequency is 4.998 MHz then the final frequency is $150-145-4.998=0.002MHz$, apparently if the digital phase detector instrument clock is uniform the phase detect precision is elevated 100 times, certainly the higher the precision is , the more difficult the technology is .If the oscillator precision can not ensure the measurement precision three levels even four levels frequency difference mode is adopted to solve it.

2. The clock precision of the digital phase detector instrument has great influence as such. We still assume $\Delta\phi$ is equal to $0.002MHz$, when the clock period is equal to $100ns$ and $20ns$ separately the counted number is 5000 and 25000, thus the distance measurement precision is 0.04m(200/5000) and 0.008m(200/25000). So to improve the measurement precision the clock precision should be elevated if possible.

3. The consistency of mixers and phase detector should be as higher as possible, thus the hardware error influence will be small. It is one of the difficult points of this method out of question.

Conclusion: The method of near field passive localization based on phase measurement technology by frequency difference presented in this paper is differ from the traditional method, it elevates the measurement precision of near field passive measurement greatly. There will be a great application prospect along with the solving of several key techniques.

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