sound speed is c. The coordinates of sound source are:

$$r = \left(d^2 - c^2 \sum_{i=1}^{4} \tau_i^2 \right) \Big/ \left(2c \sum_{i=1}^{4} \tau_i \right) \quad (16)$$

$$\varphi = \arctan\left((\tau_2 - \tau_4)/(\tau_1 - \tau_3) \right) \quad (17)$$

$$\theta \approx \arcsin\left(((2c)/d) \sqrt{(\tau_1 - \tau_3)^2 + (\tau_2 - \tau_4)^2} \right) \quad (18)$$

Assume that the variances of time delay estimation are all σ_r ,the variances of θ, φ and r are:

$$\sigma_{\varphi\tau} = \sqrt{(\frac{\partial\varphi}{\partial\tau_1}\sigma_\tau)^2 + (\frac{\partial\varphi}{\partial\tau_2}\sigma_\tau)^2 + (\frac{\partial\varphi}{\partial\tau_3}\sigma_\tau)^2 + (\frac{\partial\varphi}{\partial\tau_4}\sigma_\tau)^2} \quad (19)$$

$$\sigma_{\theta\tau} = \sqrt{(\frac{\partial\theta}{\partial\tau_1}\sigma_\tau)^2 + (\frac{\partial\theta}{\partial\tau_2}\sigma_\tau)^2 + (\frac{\partial\theta}{\partial\tau_3}\sigma_\tau)^2 + (\frac{\partial\theta}{\partial\tau_4}\sigma_\tau)^2} \quad (20)$$

$$\sigma_{r\tau} = \sqrt{(\frac{\partial r}{\partial\tau_1})^2\sigma_\tau^2 + (\frac{\partial r}{\partial\tau_2})^2\sigma_\tau^2 + (\frac{\partial r}{\partial\tau_3})^2\sigma_\tau^2 + (\frac{\partial r}{\partial\tau_4})^2\sigma_\tau^2} \quad (21)$$

$$\sigma_{\varphi\tau} \approx \frac{2\sqrt{2}c}{d\sin\theta}\sigma_\tau \quad (22)$$

$$\sigma_{\theta\tau} \approx \frac{4\sqrt{2}c}{d\cos\theta}\sigma_\tau \quad (23)$$

$$\sigma_{r\tau} \approx \frac{4rc\sqrt{(\frac{d}{2})^2 + r^2}}{(\frac{d}{2})^2(4 - \sin^2\theta)}\sigma_\tau \quad (24)$$

It can be seen that the errors of θ and φ are not relative to φ, which are relative to c, d and θ, so one error factor is reduced for the direction location of sound source for five element array. The location precision is not relative to the azimuth direction, which can notably improve the location precision at the azimuth direction.

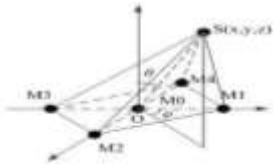

Fig.3: Five element sensor array.

4. Conclusion

The method proposed in this paper includes an improved PHAT-GCC time delay estimation algorithm and location algorithm based on it. The simulation results indicate that the improved time delay estimation algorithm is more suitable for public places with non-Gauss noise than traditional algorithm. At the same time, the research results reveal that the cross shaped array with five elemnets has better loaction performance than the cross shaped array with four elemnets because it can eliminate the effect of location error caused by azimuth angle. The research results in this paper can provide a new sound source location method for practical applications.

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