Why don't we use free 868 MHz band for geolocation?

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Abstract— **Geolocation with ultra wide band signals has seen much progress in recent years. Nevertheless, the use of narrow band signals hasn't been studied rigorously despite its advantages that we present in this paper. We study the case of using low power carrier signal from the ISM [Industrial, Scientific & Medical] radio bands, where each user that have to be geolocated accesses to a statistical frequency from the band [868, 870 MHz]. The modulating signal is a square of 100Hz frequency and the Method used for geolocation is TDOA.**

***Index Terms*— geolocation, ISM band, narrow band signals, TDOA, CRLB.**

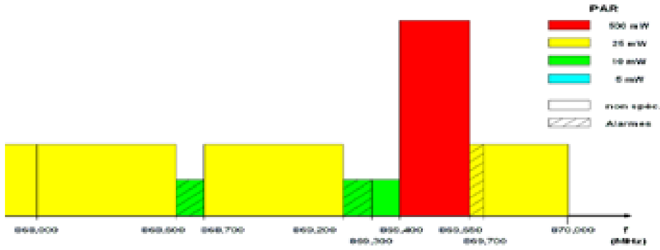
Introduction

Geo-localization has seen much progress using radio waves (GPS, Wi-Fi, Bluetooth, RFID, ULB, and GSM), video or infrared. Problems of these solutions are: high consummation due to the use of wideband, which is expensive, and limitations of reach.

This paper aims to define a new free localization system based on narrow band, low power and long-range signals.

I. Signals Used

We use signals from ISM[1] band (Industrial, scientific and medical). For question of performances, the band used is 868 MHz. We have channels of 200 kHz inside the band [868,870MHz]. Inside this interval, the apparent power which is radiated differs in function of sub-bans, the following figure illustrates that.



We use a statistical frequantial repartition to choose one frequency that will have the emitted signal. More precisely, inside each channel of 200 kHz which is centered on f_c, the emitted signal will have a frequency that is far by f_i from f_c. The bandwidth of each emitted signal is around 100Hz which represents number of symbol bits emitted.

II. Brief Description of the Algorithm

We describe in the following a DTOA estimator based on known data and symbol filter of a simple BPSK narrowband signal.

The sent signal is modeled by:

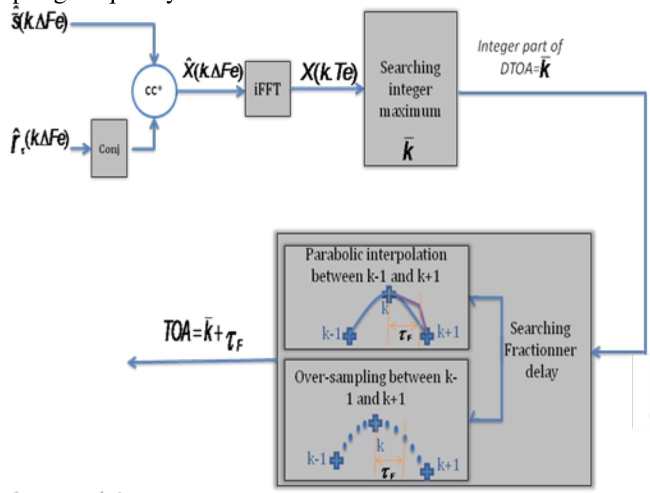
$$\tilde{\hat{S}}_{\tau} = \sum_{k=0}^{\infty} d(k).p(t-k.T_s)$$

Where d(k) are the know data and p(t) is the symbol filter shape.

The received signal in AWGN channel is then:

$$\hat{r}_{\tau} = \sum_{k=0}^{\infty} d(k).p(t-k.T_s-\tau)$$

The DTOA estimator samples the received signal at the sampling frequency Fe = 1/Te



*: cross correlation

We can see in the previous chain the steps of our algorithm:

- We use cross-correlation method for estimating TOA: The emitted and received synthesized signals are correlated in frequency domain;
- We transform to temporal domain the correlated signal;
- We look for the integer maximum of correlated signal to find integer part of the delay ;
- We look for fractional delay using two methods:
  - Parabolic interpolation between integers previous and following the integer representing delay ;
  - Over-sampling between integers previous and following the integer representing delay ;

  Notice: Looking for fractional delay of TOA by over-sampling gives the same results as the one given by parabolic interpolation.
- TOA is finally given by the sum of fractional and integer parts.

III. Theoritical bound

Many of bounds exist in the literature. The two approaches that are the most popular are: Cramer-Rao bound if we consider that the signal is deterministic and RMSE if we consider that the TOA is a Bayesian quantity. We present here our study in the deterministic case.
We suppose that the TOA is a deterministic quantity and we consider the pdf of the vector $x=[x(1), x(2),..., x(N)]^T$ which is set by TOA.
If the TOA is unbiased, the Cramer-Rao bound gives the expression of the minimum covariance that we can attain when estimating TOA.
Here below, the expression of the CRLB in the case of unbiased TOA:

$$\left\{ \begin{array}{c} \text{If the TOA is unbiased} \\ \equiv \\ E(\hat{TOA} - TOA) = 0 \end{array} \right\} \Rightarrow \left\{ CRLB = \frac{1}{8.\beta^2.\pi^2.SNR} \right\}$$

With:

$$\beta^2 = \frac{\int_{-\infty}^{+\infty} f^2.|P(f)|^2.df}{\int_{-\infty}^{+\infty} |P(f)|^2.df}$$

P (f) represents Fourier transform of transfer function of shaping filter.
In our case, we took: β=60Hz

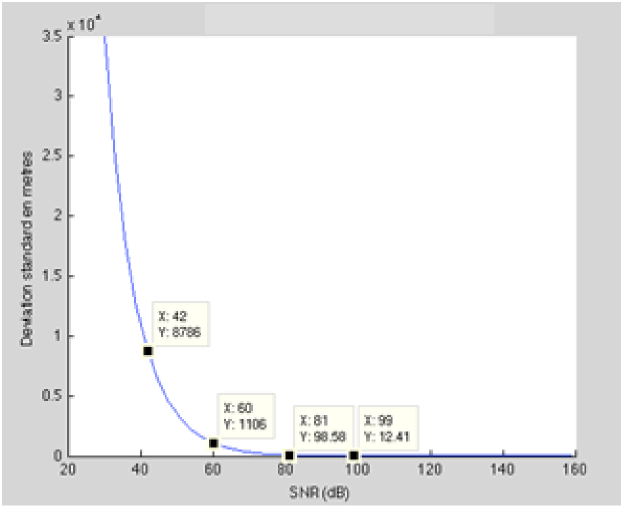
SNR's expression is given by:

$$SNR = \frac{E_S}{N_0.B} = \frac{N.E_B}{N_0.B}$$

With:

E_s: Energy symbol
E_B: Energy bit
N: Number of emitted bits
N_0: Level of noise
B: Bandwith

[Estimation of this SNR is done in the following part]
We represent the CRLB in meters in function of SNR in the following figure:



IV. Estimation of SNR

In order to calculate SNR for CRLB, we calculate symbol SNR on a bandwidth of 2.B.
We have:

$$SNR^S_{2.B} = \frac{E_b.N_{bits}}{N_0.B}$$

$$SNR^S_{2.F_e} = \frac{E_b}{N_0.B}$$

From these formulas, we can clearly see that having narrow band signals with small B, increases SNR.
From (1) and (2)

$$SNR^S_{2.B} = SNR^S_{2.F_e} \times \frac{F_e}{B} \times N_{bits}$$

We also have:

F_e=Frequency of sampling= 48 kHz

And

$$B = \frac{1}{T_S} = \frac{1}{Widthofshapingfilter} = 100Hz$$

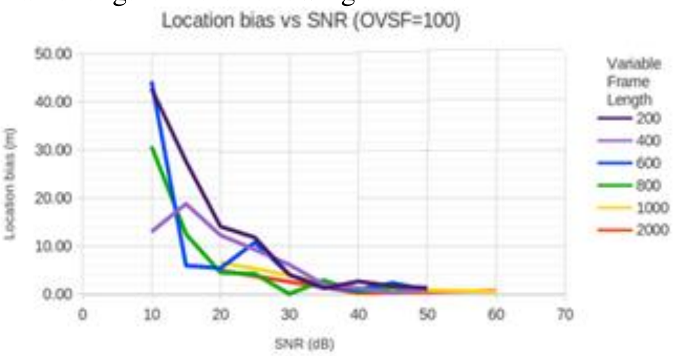
So

$$SNR^{S}_{2.B_{dB}} = SNR^{S}_{2.Fe_{dB}} + 10\times\log(\frac{F_e}{B}) + 10\times\log(N_{bits})$$

$$SNR^{S}_{2.B_{dB}} = SNR^{S}_{2.Fe_{dB}} + 10\times\log(480) + 10\times\log(N_{bits})$$

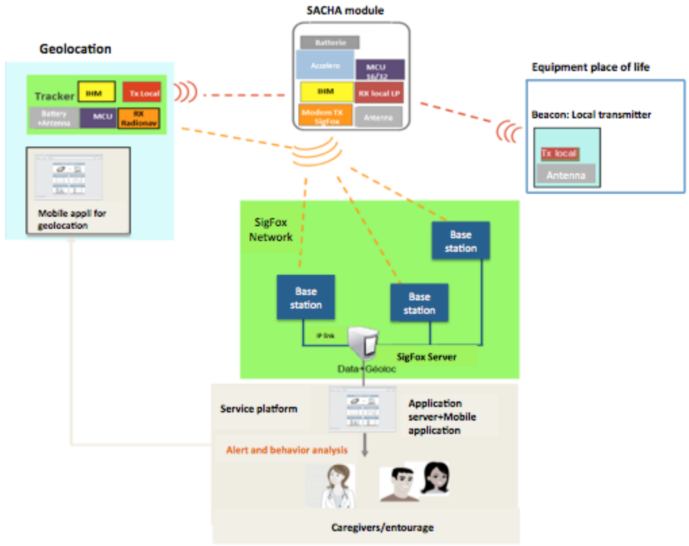
$$SNR^{S}_{2.B_{dB}} = SNR^{S}_{2.Fe_{dB}} + 26dB + 10\times\log(N_{bits})$$

We can see the RMSE in function of SNR with different frame lengths in the following scheme.



V. Application

This geolocation with these signals found its application in a regional project which name is SACHA (Search and Computerize Human Acts), that aims developing a solution of long range tracking of the frail, dependent or demented elderly combining fugue control, fall detection, access control and remote alarm. This application is based on a miniaturized flexible bracelet which is sending signals described in the first part. It is addressed to institutions and hospitals, to nurse's aide and to families of people with Alzheimer's disease.



VI. Conclusion

We saw that despite of the current trend that is using essentially ultra-wide band signals, narrow band signals gives good performances of geolocation. We also saw that the SNR is much better in these conditions and that this solution was adopted for an industrial project thanks to its low cost. We are working actually on improving performances of geolocation by using adaptative algorithms.

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