ver sensitivity before transmission was -31.5 dBm at a BER of 10^{-9}. The sensitivity degradation from the shot noise limit was 10.4 dB with a bandwidth of 14 GHz. The 3 dB degradation is caused by receiver thermal noise. The 0.5 dB degradation caused by the LD phase noise can be calculated using the beat linewidth and the differential detector delay time.[5] The residual degradation is an artefact of IF circuit nonideality.

The sensitivity degradation occurs after 163 km and 202 km transmission because of fibre chromatic dispersion. There is a floor in the error rate characteristic for transmission distances longer than 163 km. This is because the waveform is changed after demodulation by the fibre chromatic dispersion, and the decision timing and decision level deviate from optimum values. Error rate performance after inserting the delay equaliser is shown in the same Figure. The sensitivity degradation caused by fibre chromatic dispersion is successfully equalised by the delay equaliser. The equaliser dispersion characteristic corresponds to 182 km fibre dispersion which is 16 ps/km/nm. There was no degradation of receiver sensitivity caused by the residual dispersion in the remaining of 20 km fibre.

Conclusion: A wideband double balanced optical receiver was proposed. Degradation caused by fibre chromatic dispersion is successfully equalised by a novel microstrip line delay equaliser. With the delay equaliser and wideband optical receiver, an 8 Gbit/s 202 km optical CPFSK transmission experiment was conducted at a wavelength of $1.55 \mu m$ with a $1.3 \mu m$ zero dispersion single-mode fibre.

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SIMPLE PARAMETER ESTIMATION TECHNIQUE IN MANOEUVRING TARGET TRACKING SYSTEM

Indexing terms: Radar, Correlation, Noise

The measurement noise in a manoeuvring target tracking system is significantly correlated for high measurement frequencies. If some correlation parameters are unknown, a complicated procedure is usually required further estimation. A simple estimation technique is presented when the manoeuvre detection method is used for tracking the target.

Introduction: The measurement noise of noisy radar data is usually assumed to be white. A conventional Kalman filter is

often used for tracking nonmanoeuvring targets. If the target is manoeuvring, the conventional Kalman filter must be modified to keep the tracking performance. There have been several approaches to this problem.[1]

In practice measurement noises are not white. Noises are autocorrelated within a bandwidth of typically a few hertz.[2] In many modern radar systems, the measurement frequency is usually high so that the correlation can not be ignored. Treating the correlated noise as a first order Markov process, the noise can be decorrelated in such a way that the (modified) Kalman filter is effective after decorrelation.[2,3]

Some correlation parameters are often unknown. The unknown parameters must be estimated online before the decorrelation. It is generally very complicated to perform this parameter estimation in manoeuvring target tracking system. In this letter, we show a simple and effective approximation which is applicable if the manoeuvre detection method[4] is employed for tracking the manoeuvring target.

Manoeuvring target tracking: Modelling the manoeuvre variable (acceleration) as a first order autoregressive process and treating the acceleration as part of the state vector, Singer[5] derived the target motion and radar measurement models for the manoeuvring target

$$X_{k+1} = \phi X_k + G w_k \tag{1}$$

$$Z_k = H X_k + v_k \tag{2}$$

where X_k, Z_k, w_k and v_k are target state, measurement data, process noise and measurement noise, respectively. The coefficient matrices ϕ, G, H and Q $(= E\{w_k w_k^T\})$ were shown in Reference 5.

If the measurement noise v_k is white, the system governed by eqns. 1 and 2 can be processed by the conventional Kalman filter. Tracking the manoeuvring target in this way assumes the target is always manoeuvring. When the target is in a nonmanoeuvring condition, some noises will be treated as if the target is manoeuvring. The estimation errors for both position and velocity are increased when this occurs. To enhance the performance, the manoeuvre detection method[4] is used. In general, the tracking system works well in nonmanoeuvring mode. A manoeuvre detector operates simultaneously to monitor the occurrence of a manoeuvre. When a manoeuvre is detected, the system switches to manoeuvring mode until the manoeuvre is discriminated to disappear. The system then reverts to the nonmanoeuvring mode.

Parameter estimation: Assume the noise can be modelled as a first-order Markov process[2] given by

$$v_k = \lambda v_{k-1} + \nu_k \tag{3}$$

where λ is the correlation coefficient and ν_k is a zero mean white Gaussian noise.

If all the parameters, including λ and R $(= E\{\nu_k \nu_k^T\})$, are known, the correlated noise v_k can be decorrelated so that significant improvement of the system performance can be obtained from the decorrelation process.[3] The parameters λ and R are usually unknown and should be estimated before the decorrelation process. In the manoeuvring target tracking system, this parameter estimation is generally very complicated. If the manoeuvre detection method is used for tracking the manoeuvring target, a simple estimation technique may be employed.

Since the manoeuvre detection method can classify the target into either manoeuvring or nonmanoeuvring state, the parameters can be estimated in the nonmanoeuvring period. In nonmanoeuvring condition, the process noise is approximately zero so that the state estimation errors will be very small when the system has a steady state response. This phenomenon holds even if the correlation effect is ignored. The innovation ε_k $(= Z_k - H\hat{X}_{k|k-1} = H(X - \hat{X}_{k|k-1}) + v_k$, $\hat{X}_{k|k-1}$ is the predicted state) will be dominated by the correlated measurement noise v_k. The autocorrelations of the innovation can be approximately represented by the parameters λ and R. From eqn. 3, we obtain

$$\rho_j = E\{\varepsilon_k \varepsilon_{k-j}\} \approx E\{v_k v_{k-j}\} = \lambda^j R \qquad j = 0, 1, \ldots \tag{4}$$

The theoretical autocorrelations ρ_j can be approximated by the time-average autocorrelations $\hat{\rho}_j$ $[= (1/N) \sum_{q=k-N+1}^{k} \varepsilon_q \varepsilon_{q-j}]$. Then, from eqn. 4 and the fact that $0 \leq \lambda < 1$, the parameters λ and R can be estimated as follows.

$$\hat{R} = \hat{\rho}_0 \qquad (5)$$

$$\hat{\lambda} = [(\rho_1/\rho_0) + (\rho_2/\rho_0)^{1/2} + \ldots + (\rho_M/\rho_0)^{1/M}]/M \qquad (6)$$

The order of the autocorrelation (M) should be limited because the value of the high-order autocorrelation is very small and easily disturbed by the noise and the terms ignored in the approximation eqn. 4.

Performance evaluation: Monte Carlo simulations (30 runs in each simulation) were performed to demonstrate the accuracy of the above approximated method. The position of the target is measured every $T = 0.11$ s. The parameter estimation works when the target is in a nonmanoeuvring state. The process noise is assumed to be zero in the nonmanoeuvring period. A small manoeuvre is usually preset in the computation procedure of the Kalman filter to accommodate the nonideal case. The coefficient matrices ϕ, G, H and the computation of Q are the same as in Reference 5 with the coefficient $\alpha = 1/20$ (s^{-1}).

Table 1 shows the simulation results. The parameter estimation performance is affected by the factors λ and $\bar{\sigma}_m$ (the preset standard deviation of manoeuvre). It was found (Table 1) that this approximated method can provide good estimations for parameters λ and R in most cases, except when the correlation of the measurement noise is very large. The parameter R is a little overestimated if the correlation is small and is underestimated when the correlation is large. The parameter λ is generally underestimated. If the preset parameter $\bar{\sigma}_m$ is large, the phenomenon of underestimation becomes more obvious as the correlation increases.

Table 1 ESTIMATION ACCURACY

$\bar{\sigma}_m$	λ	mean ($\hat{\lambda}$)	RMS error ($\hat{\lambda}$)	mean ($\sqrt{\hat{R}}$)	RMS error ($\sqrt{\hat{R}}$)
	0·0	0·0606	0·0997	101·4044	6·4244
	0·2	0·1809	0·1014	101·4754	7·1929
1	0·5	0·4813	0·0816	101·2461	8·6870
	0·8	0·7785	0·0602	99·3070	12·6466
	0·95	0·9212	0·0440	86·2288	22·2793
	0·0	0·0522	0·0922	103·7409	7·4000
	0·2	0·1697	0·1002	103·6148	8·0148
10	0·5	0·4649	0·0902	102·7786	9·0991
	0·8	0·7596	0·0718	98·2436	12·4179
	0·95	0·8896	0·0750	75·2358	28·7634

$\sigma_m = 0$; $R = 100^2$; $N = 200$; $M = 2$; $\bar{R} = 100^2$

Conclusion: When the measurement frequency is high, the correlation of the measurement noise is significant. The correlated noise can be decorrelated if all the parameters in the system are known. When there are some unknown parameters they should be estimated before the decorrelation process. This parameter estimation procedure is generally very complicated in manoeuvring target tracking system. If the manoeuvre detection is used for tracking the manoeuvring target, a simple technique is available for estimating the parameters.

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CACHE MEMORY REPLACEMENT POLICY FOR A UNIPROCESSOR SYSTEM

Indexing term: Memories

Cache memory hierarchies are used to buffer those portions of main memory with the most frequent use by the CPU. As cache memory is very costly, good design techniques must consider small cache sizes maintaining high levels of use (hit ratio) and ease of implementation. The memory replacement policy is important in maintaining a high hit ratio. Most replacement policies used are easily implemented when the main memory has fixed page locations. A new cache algorithm using a variable page configuration is explained in terms of program behaviour.

Introduction: Cache systems were mainly found in mainframes and minicomputers where CPU memory requests far exceed the access and cycle times of dynamic random access memory (DRAM). Cache systems are currently emerging in microcomputers because of the increased speed and power of microprocessors. The techniques for utilising a cache memory system in multiuser and multiprocessor environments have been well understood for some time.[3,5-7] More efficient techniques can be implemented in microcomputers because they are single user uniprocessor environments.

Memory replacement policies have traditionally been grouped into three main classes.[2] Class 1 algorithms use no information about memory usage and either randomly selects a block for replacement or uses a heuristic rule. Two examples of such a class are RAND and FIFO.[2] Class 2 algorithms use information corresponding to the most recent usage. An example of this is LRU which discards the least recently used block.[2,4] Class 3 algorithms also use information of a block's absence from memory. An example for this class would be the ATLAS algorithm.[1,2] The new algorithm introduced in this letter is from a class known as location policies.[8] It is based on the location (address) of the block required in main memory with respect to the locations of the blocks already in the cache memory. One rule may be to replace a block of data in cache that contains main memory locations directly below the block needed. Location policies are easily understood by visualising the memory hierarchy.

Nomenclature: Page: The number of sequential words in main memory transferred to cache memory when a miss occurs. The number of words in one page is denoted by m. A page is sometimes referred to as line size[7] or block.

Page frame: Cache memory that can buffer one page of main memory. A page of main memory and a page frame of cache memory contain the same number of words. The number of page frames in cache is denoted by n.

Memory configuration: The total number of words in cache the number of page frames multiplied by the page frame size, nm. Fig. 1 shows a conceptual view of a cache/main memory hierarchy where the variable M represents the total number of words in main memory. Fig. 1 can be considered as a snap shot in time of the memory hierarchy. It shows which locations of main memory, exist in each cache page frame of size m words. The locations which do not exist in cache can also be inferred, i.e. those between the frames. This gives a sense of distance from frame to frame.
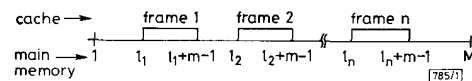
Fig. 1 *Horizontal representation of memory hierarchy*