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低軌道衛星通訊基頻接收器軟體設計研究
委託研究計畫申請書

(計畫書封面藍底黑字，並請裝定成冊)

中文計畫名稱：低軌道衛星通訊基頻接收器軟體設計研究

英文計畫名稱: Software Design Research for the Baseband Receiver of Low-orbit Satellite Communications

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一、綜合資料： (格式大小為A4紙)

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二、(1)計畫摘要：(請分別以中、英文就全部計畫要點作一概述，以五百字為限)中文部分

(關鍵詞：低軌道衛星通訊,同步,基頻接收設計,衛星鏈路分析)

為了建立我們設計低軌道衛星通訊接收機(包含軟硬體實作)的能力. 我們依循福衛2號front-end Mira board的基頻接收機著手設計. 我們從整體系統規格, 介面(包含ECL/LVDS,TIME CODE)延續,以達到基頻接收端的高速率資料追縱. 在本計畫中,我們將從架構,規格,系統方塊圖,實作設計,Matlab/C實作到模擬, 來呈現根據Formosa-2衛星通訊系統的要求的基頻接收機設計. 以建立台灣自主低軌道衛星通訊能力.

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(2)計畫摘要：英文部分

(Keywords：LEO Satellite Communications, Synchronization, Receiver Baseband Design, Satellite Link Analysis)

In order to build up own design capability for LEO remote-sensing satellite communication receiver capability including hardware and software implementation, we proceed the design of baseband receiver for Foremosa-2 front-end Mira board. We proceed from entire system specification, interface (ECL/LVDS, time code, ..), to achieve high-rate data acquisition from baseband receiver. Based on Formosa-2 satellite system requirements, we will deliver the baseband design of receiver in this project, from architecture, specifications, block diagram, implementation design, MATLAB/C implementation, to simulations (in floating-point). It is expected to establish Taiwan's own design capability in LEO satellite communication receiver.

三、本委託計畫之背景目的、重要性以及國內外有關本計畫之研究情況，並註明重要文獻。

The purpose of this project is to design a satellite communication baseband receiver to meet the system requirement of Formosa-2 satellite system, to reach the purpose of self-control key technology. It is a low-orbital satellite with average height 891km. The communication system parameters include (D)QPSK with concatenated codes to support up to 120M bps over 120M Hz bandwidth. In this proposed project, we shall develop own technology to design LEO satellite baseband receiver and its simulations. The key to success of system integration like this project would be the confirmation of system specification and interface functions. Based on our extensive hand-on experience in satellite communications (PI has worked on INMARSAT, DVB-S, etc. different kinds of satellite communication systems), we will work closely with NSPO to inverse the need of this LEO satellite communication link requirements. Bases on this step, the baseband receiver shall include ECL/LVDS Interface, high rate acquisition and time code interface. The functions of baseband design include frame-sync, unscrambling and RS decoding, which shall be facilitated by block/module design concept. We can therefore complete the design of baseband receiver and evaluate real implementation.

In the following, we will introduce background technology for LEO satellite baseband receiver design:

A) Channel modeling

Most of the research on satellite communications indicated that the elevation angle of the signal's transmission path influences the link quality. A few elevation-dependent channel models have been proposed to describe the fading statistics of the received signal at the specified elevation angles. For example, Bischl *et al*. [2] proposed an elevation-angle-dependent Rican-Rayleigh/lognormal channel model in which a fading process yields state transitions between unshadowed areas (a good channel state) and shadowed areas (a bad channel state). Similarly, Corazza and Vatalaro [3] propose another elevation-depended channel model. The model assumes flat fading and has found very good matching with experimental data collected in Canada [4] and in Europe by the European Space Agency (ESA) in several test campaigns embracing open and suburban environments with satellite elevation up to 80°. Furthermore, it is suitable for all types of environment, such as rural, suburban and urban, simply by tuning the model parameters. We briefly state the PDF and parameters for it in the following paragraphs.

Another satellite channel modeling is regarding ionospheric scintillation. According to the explanation in [5] an ionospheric scintillation is caused by a flash of light produced in certain materials when they absorb ionizing radiation. Ionospheric scintillation also impacts the communication between a satellite and the earth station in a significant way. We will also go through this phenomenon and state the related literatures.

◆ *The Amplitude PDF of Rice-lognormal Channel*

The amplitude PDF of Rice-lognormal channel model is expressed as:

$$p_r(r) = \int_0^\infty p(r \mid S) p_S(S) dS$$

where

$$p_r(r \mid S) = \frac{2r(1+K)}{S^2} e^{-K-\frac{(1+K)r^2}{S^2}} I_0\left(\frac{2r}{S}\sqrt{K(1+K)}\right), \; r \geq 0$$

and

$$p_S(S) = \frac{1}{\sqrt{2\pi} h\sigma S} e^{-\frac{1}{2}\left(\frac{\ln S - \mu}{h\sigma}\right)^2}, \; S \geq 0.$$

$p_r(r \mid S)$ is the Rice PDF conditioned on a certain shadowing S, where I_0 is the zero order modified

Bessel function of the first kind, and K is the so called Rice factor. $h = \ln(10)/20$, μ and $(h\sigma)^2$ are the mean the variance of the associated normal variation, respectively. In terrestrial channel σ is usually referred to as the "dB spread."

As the elevation angle of satellite link θ inferences the PDF of the received signal, the parameter K, μ and σ are modeled as functions of θ by data fitting to the measured data [1]. The resulting empirical formulas for θ in a range of $20^\circ < \theta < 80^\circ$ are expressed as:

$$\mu(\theta) = \mu_0 + \mu_1\theta + \mu_2\theta^2 + \mu_3\theta^3$$
$$K(\theta) = K_0 + K_1\theta + K_2\theta^2$$
$$\sigma(\theta) = \sigma_0 + \sigma_1\theta$$

The coefficients for the specific example are reported in Table 1 and the resulting PDF of the received signal amplitude are shown in Figure 1.

Table 1 Coefficients for empirical formulas.

K	μ	σ
K_0=2.731	μ_0=-2.331	σ_0=4.5
K_1=-1.074x10^{-1}	μ_1=1.142x10^{-1}	σ_1=-0.05
K_2=2.774x10^{-3}	μ_2=-1.939x10^{-3}	
	μ_3=1.094x10^{-5}	

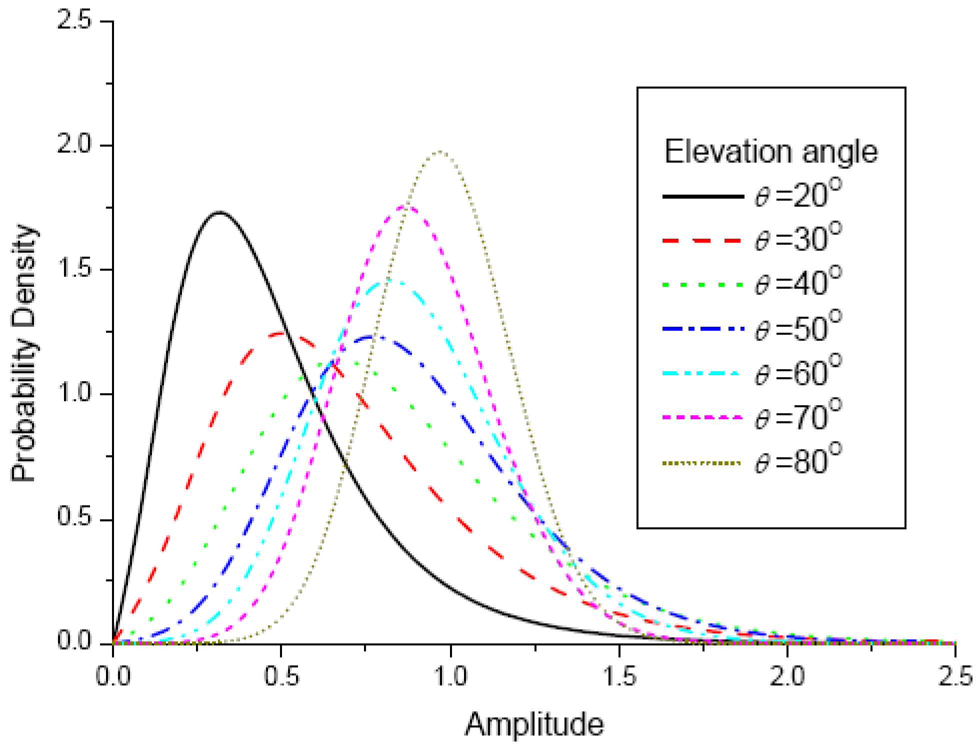


Figure 1 The received signal amplitude PDF for Rice-lognormal channel at different elevation angles [1].

◆ *Ionospheric Scintillation Channel*

The ionosphere scintillation is that part of the earth's atmosphere, where ions and free electrons are presented in quantities sufficient to affect the propagation of radio waves. The structure of the ionosphere is a balance between solar production and the destructive processes of recombination. The electron density undergoes a strong daily variation, especially at sunrise and sunset, as well as annual fluctuations. In general, ionosphe re is divided into different layers according to the electron density presented, which is always equal to the ion density [5].

The amplitude scintillation index S_4 is one of the most important parameters in ionospheric scintillation study and is defined as the normalized variance of intensity of the signal [6]

$$S_4{}^2 = \frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2}$$

where denotes the process of ensemble averaging and *I* is the intensity of the signal amplitude. It is shown that S_4 can be approached to *m* parameter of the Nakagami-*m* distribution through $m = 1/S_4{}^2$ [1]. Note that the Nakagami-*m* distribution approaches the Rice distribution resembles a weak scintillation case and equals the Rayleigh distribution for a strong scintillation case.

It is well known that when radio wave traverses drifting ionospheric irregularities, it experiences amplitude fading, phase fluctuation, and angle of arrival variations, and collectively the effect is ionospheric scintillation. Scintillation techniques have been developed by observing fluctuations in the amplitude and phase of satellite beacon signals propagating through the ionospheric irregularities. Results show that solar activity and geomagnetic disturbances are the main factors causing ionospheric irregularities. The scintillation in the received signal thus depends on sunspot number, geomagnetic index, radio frequency, ionospheric latitude and longitude, day of year and time of day [1]. Empirical data also shows that equatorial ionospheric scintillation occurs quite often between local sunset and midnight for earth stations operating in L-band and lower frequencies [7]. This should be of concerned to system designers.

B) Satellite tracking

Satellite tracking had been an import issue since the first launched satellite, Sputnik, in 1957 by USSR [8]. Satellite tracking aims to track the position of a non-geostationary satellite, is the key to provide real-time service to users.

The first literature discussing tracking the earth satellite was appeared in Proceedings of the IRE by John T. Mengel in 1956 [9]. The method proposed in [9] uses phase-comparison techniques. By phase-comparison techniques, these ground stations will measure the angular position of the satellite as it passes through the antenna beam, recording its “signature” automatically without the need for initial tracking information. The novelty of phase-comparison technique can be shown in Figure 2.

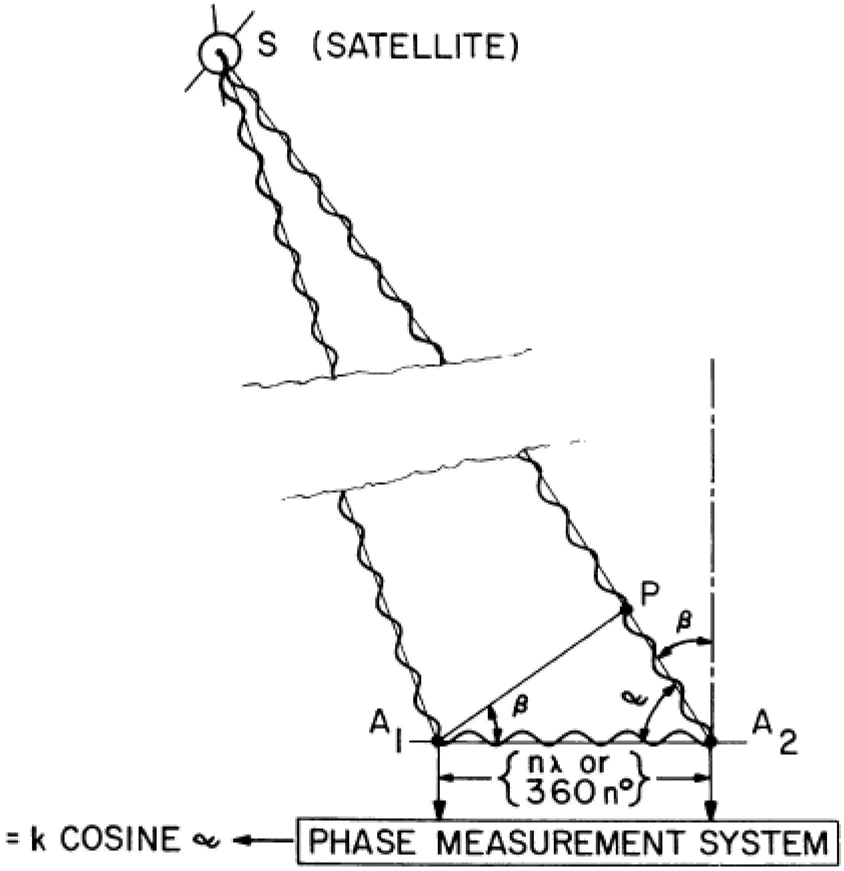


Figure 2 Phase-comparison technique [9].

Over the past 30 years since John’s pioneering work in 1956, work has progressed so that four classes of tracking system have evolved to meet the various needs of satellite communications. These can be described as [10]:

- manual/programming tracking
- monopulse or simultaneous sensing
- sequential amplitude sensing
- electronic beam squinting

These works can be summarized in Table 2.

Table 2 Summary of satellite tracking systems [10].

Tracking category	Subcategory	Remarks	Performance	Usage
Manual		Non-autotracking; Simple; Requires operator	Tracking accuracy dependent on operator-generally low	Many stations can revert to manual tracking if other tracking methods fail

Program steering		Non-autotracking; Simplistic with modern technology; Requires operator intervention; Accuracy reliant on orbit prediction	Tracking accuracies approaching 0.01^0 possible	Often employed as back-up in case primary tracking system fails
Monopulse	Simultaneous probing Multimode ● TM_{01} ● TM_{01}/TE_{21} ● orthogonal ● TE_{21}	Autotracking tracking information obtained in a single time frame; 2, 4, or 8 channel coherent receiver required; expensive	Tracking accuracy very good, typically 0.005^0; Operational SNR~15 dB; Fast dynamic response	Widespread in many of the larger earth stations; also shipborne terminals, sat-to-sat comms
Conical scan	Rotation of antenna; Rotation of offset feed; Rotation of sub-reflector; TM01 mode; TM01/TE21 mode; Conopulse	Autotracking; Sequential amplitude sensing system; sensitive to AM interference; Mechanically complex; Uses single channel receiver; Methods 1-3 result in modulation of uplink transmission	Tracking accuracy typical 0.01^0; Operational SNR~30 dB; Medium dynamic response	Widespread up until mid 70s; Monopulse and step-track then preferred
Step-track	Step antenna; Noddling subreflector	Autotracking; Sequential amplitude sensing system; sensitive to AM interference; Simple low cost system; Single channel receiver; Method results in	Tracking accuracies of 0.01^0 have been obtained, typically $< 0.1^0$; Operational SNR~30-45 dB; Slow dynamic response	Widespread where lower accuracy acceptable and cost important; Many of the smaller earth stations, shipborne terminals

		high wear of mechanical drives		
Electronic beam steering	Dipole feed; TM_{01}/TE_{21} mode; Conversion techniques	Autotracking; Pssudoamplitude sensing system; Much reduced sensitivity to AM interference; Uses single channel receiver; Relatively simple	Tracking accuracy approaching monopulse, 0.005^0 ; operational SNR 15-30 dB; fast dynamic response	Use limited to mainly experimental tracking systems; Shows good overall tracking performance; Well suited to sat-to-sat comms; Should be widely used in future

Owing to the development of computing capability and digital signal processing technique, researches regarding satellite tracking have progresses in the recent 20 years. A few projects aim at implementing tracking controller using either hardware or software are proposed in the following literatures, e.g., [11]-[15].

LEO satellite system is playing an increasing important role in future worldwide mobile telecommunications. One of the difficult technical issues encountered in LEO is the high speed of these satellites relative to the mobile terminals. Thus, accurate and efficient methods of tracking the satellites are required. There had already been many algorithms for satellite tracking. The algorithm proposed in [16]. In this paper, an efficient antenna pointing algorithms allowing the mobile terminals to track their own movements of the LEO satellites is proposed. This algorithm aims to detect the signal strength of the LEO satellite and then tries to adjust the angles antenna in two orthogonal ways. This algorithm is shown in Figure 2. In particular, this algorithm is mainly developed for a vehicle-based mobile mobility model.

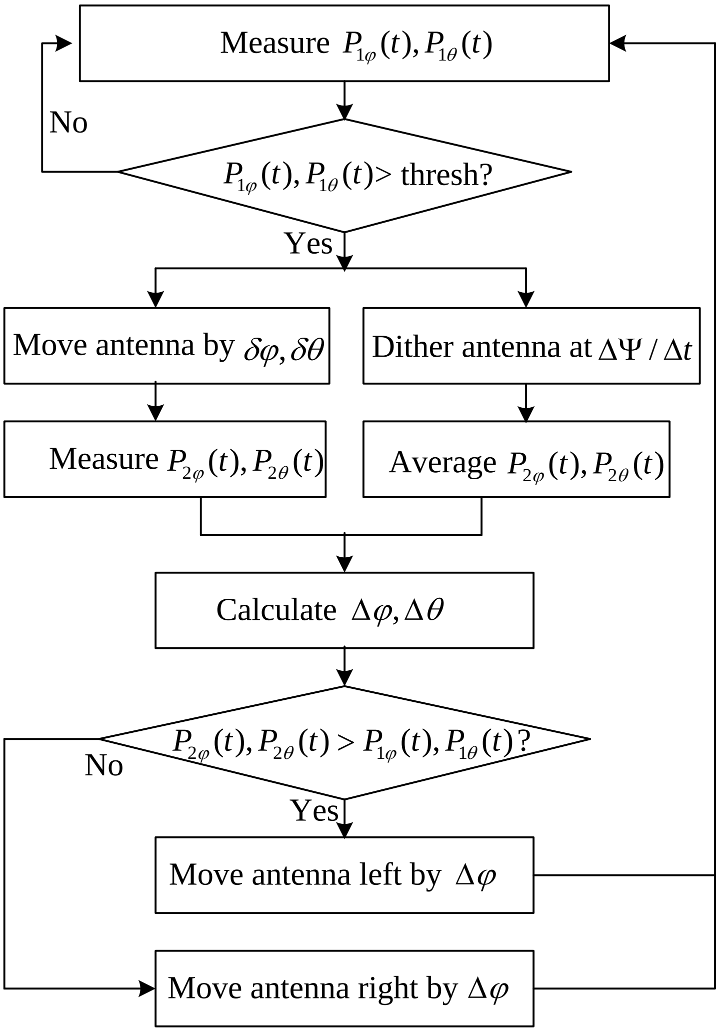


Figure 2 Flowchart [16].

Except for the algorithm given in [16], a phased array antenna system is also a feasible solution for LEO satellite tracking. A ground receiving phased array antenna system is described for tracking and communication with satellites in LEO in [17]. Different active array antenna architectures and the minimum number of array elements for meeting the system requirement are evaluated and compared. A general noise temperature model is also developed for evaluating any phased array antenna system in [17]. The block diagram of a phased array antenna is shown in Figure 3. More literatures on phased array antennas can be found in [18]-[20].

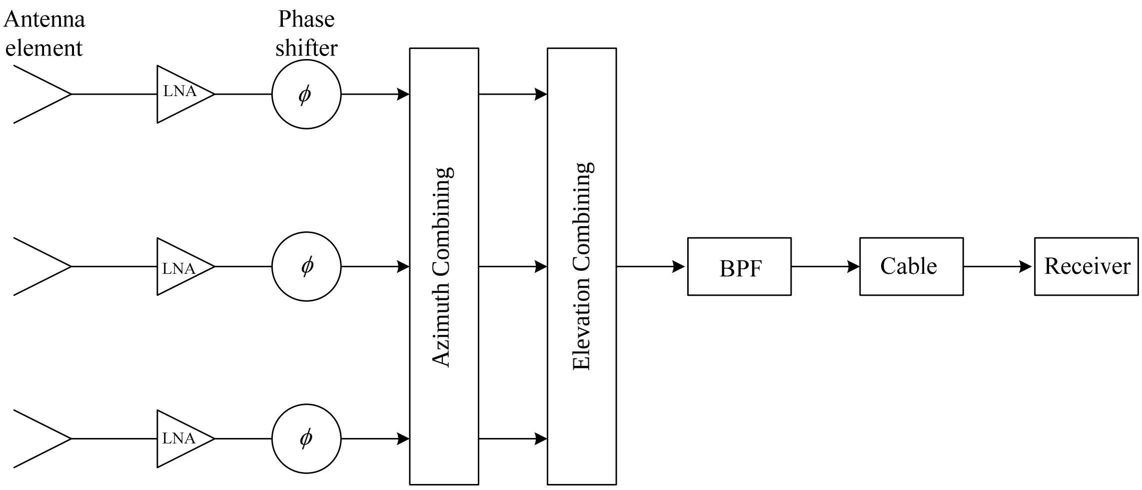


Figure 3 Active array antenna block diagram [17].

C) Synchronization

Synchronization techniques for satellite communications can be viewed through different perspectives. We may regard this issue from a network perspective or we may regard this issue at only the downlink receiver (earth station). If the problem is focused on the downlink receiver, the synchronization technique should at least have a synchronization procedure and subsequently timing/frequency synchronization should be established. If re-examine this issue from the network level, the problem should be treated in another way. A comprehensive review on terrestrial/satellite network synchronization is presented in [21].

For more terrestrial/satellite network synchronization, we list some literatures for further reading, e.g., [22]-[25].

Regarding the synchronization procedures for a satellite communication system, [26] provides a procedure for network access and synchronization procedures. The procedures include

- initial synchronization
- access channel acquisition
- fine synchronization control

The system architecture and performance evaluation are also included.

Regarding timing and frequency synchronization, there had already been many literatures involving this issue. The work by Q. Liu [27] aims at proposing a reduced-complexity frequency synchronization method for global satellite communications systems employing low earth orbit satellites or medium earth orbit satellites. In this condition, the Doppler shift varies randomly and can be more than ten times larger than the symbol rate. The proposed method uses the satellite as the reference point and corrects frequency errors accordingly. It is shown the proposed method can achieve negligibly small frequency errors. Typically, the system bandwidth can be fully utilized and guard bands are no longer needed.

In constrat to [27], A. A. D'Amico et al. [28] propose another design of efficient non-data-aided clock and carrier (frequency/phase) synchronization algorithms intended for use in satellite digital video broadcasting systems employing turbo-coding techniques to enhance power efficiency. The proposed clock/carrier synchronization scheme capable of operating at values of Eb/N0 as low as 1 dB with lock-in delay not exceeding 50 ms. A glance of the synchronization circuits is shown in Figure 4.

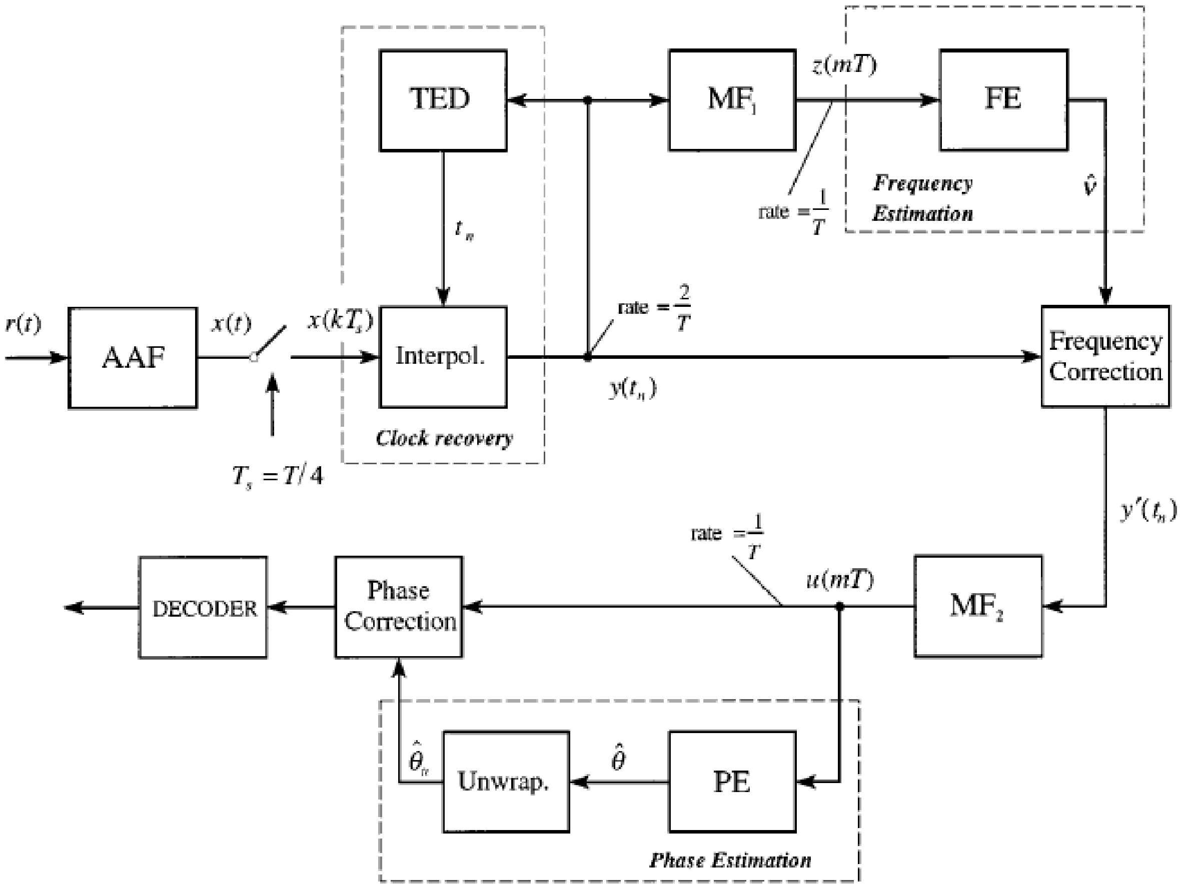
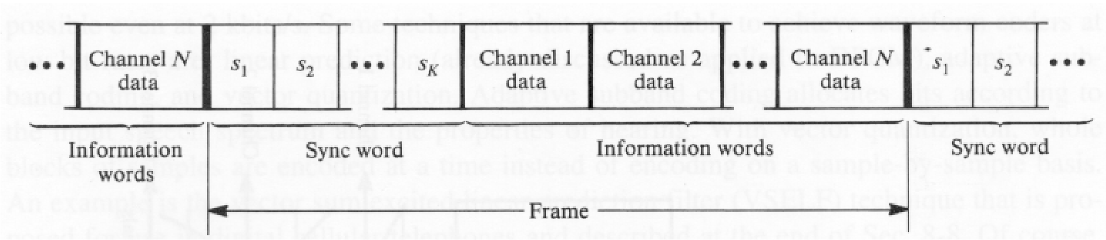


Figure 4 Active array antenna block diagram [28].

For the same objective, still many literatures intend to achieve carrier, symbol, or timing synchronization in a satellite communication channel for different modulation schemes. For example, see [29]-[33].

Another important problem to design such baseband receiver is to achieve frame synchronization, which is particularly important for image, video, etc. A data bit stream contains data arranged in a series of words, with a prescribed number of words making up a block and a given number of blocks constituting a frame. Each data frame is identified by one or more bits that are inserted at the beginning or ending of each frame or, in certain schemes, at both the beginning and ending of each frame. A commonly used frame code, known as the Barker code, is often used for frame synchronization. The sync-frame code word can be recognized during reception by a specific bit sequence consisting of N-bit segments, which are compared with an identical sync-frame word stored within the receiver data processing circuits. For example, in time division multiplexing (TDM), transmitted signal is the time interleaving of samples from several sources to form frames (Fig. 1) so that the information from these sources can be transmitted serially over a single communication channel. At the receiver the decommutator has to be synchronized with the incoming waveform so that the samples corresponding to source-1 will appear on the channel-1 output. A frame synchronizer is adapted to receive an incoming high-speed TDM or packet (time division multiplex) signal of a framed structure containing, at frame intervals, a sequence of identical synchronization bit patterns and a sequence of byte-length data signals. Frame synchronization is needed at the TDM or packet receiver so that the received multiplexed data can be sorted and directed to appropriate output channel. Frame synchronization is provided to the receiver in two different ways:

- provided to the de-multiplexer circuit by sending a frame synchronization signal from the transmitter over a separate channel
- derive the frame synchronization from the TDM or packet signal itself



TDM frame synchronization format.

Frame synchronization is usually done by correlating a unique word according to system definitions. At the baseband receiver, once frame synchronization is done, de-scrambling of signal can therefore succeed.

D) Equalization

Since the LEO satellite channel can be modeled as a multipath fading channel, for a high-quality receipt in the downlink, equalization is a necessary operation for successful reception. Through literature surveying, we find that many of the equalization techniques can be applied to a satellite channel with high Doppler shift. Equalization can be performed in either the time domain or in the frequency domain. Through these literatures, we select ten representative papers to review the development of equalizing a satellite channel.

The first discussing on nonlinear equalization of digital satellite channels are presented in [34] by S. Benedetto et al. In this paper a nonlinear equalizer structure is proposed, and its performance is analyzed. A third-order nonlinear equalizer developed in [34] is shown in Figure 5.

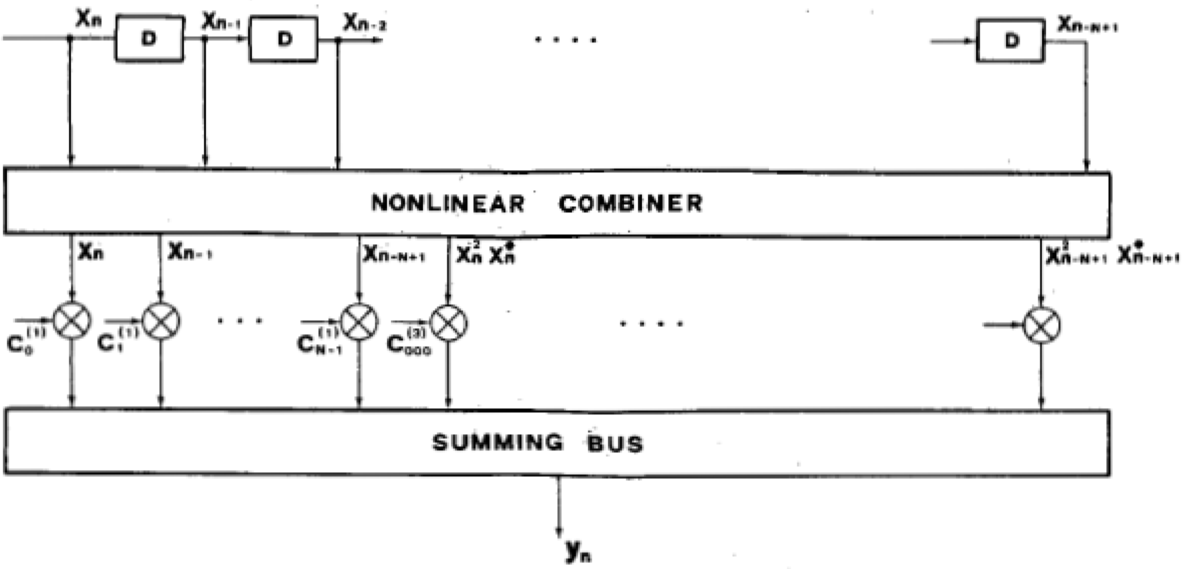


Figure 5 A third-order nonlinear equalizer [34].

Following this trend, a series of linear/nonlinear equalization schemes are applied to a satellite channel. In [35], adaptive decision feedback equalization for digital satellite channels using multilayer neural networks is proposed. Still using adaptive equalization, [36] use a frequency-domain Volterra filter to equalize a nonlinear digital satellite channel.

[37] shows that each channel states of multipath satellite channel follows a Gaussian distribution, and use a Bayesian equalization for it. Blind equalization and block equalization for single-carrier satellite communications with high-mobility receivers are shown in [38] and [39], respectively. As

compared to the many nonlinear equalizers, [40] use a linear equalization in the time-domain to equalize the nonlinear band-limited satellite channels.

[41] derives an equalization strategy for nonlinear channels based on Monte Carlo methods. The authors in [41] present a detailed performance, complexity and storage analysis. A significant performance gain compared to the linear equalizer, and the proposed technique results in a significant reduction in both complexity and storage, compared to the forward-backward equalizer. The system model used in [41] is shown in figure 6. A discrete-time channel model is used in the analysis.

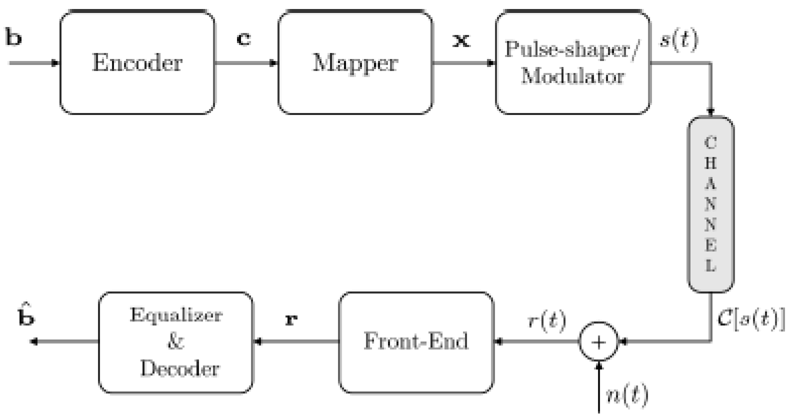


Figure 6 System model [41].

[42] considers a coded solution for compensating the nonlinear distortion of TDMA satellite waveforms through a turbo equalization. In [43], P. Peodrosa et al. use an iterative block decision feedback equalization with CFO estimator proved to be a valid receiver structure for single carrier frequency domain equalization combined with QPSK modulation.

E) Channel estimation

It is vital to build the channel estimation block for communication in a fading channel. From the previous sections, we find that the channel for a LEO satellite is a Rayleigh or Rice fading channel. We select a total of three papers regarding the issue of channel estimation in a LEO satellite channel.

Differential detection of phase-shift keying signals entails the ability to establish a stable phase reference based on previous symbol(s). In low bit-rate communications strongly affected by Doppler effect, like those making use of non-geostationary satellites, significant carrier phase drifts may occur within the symbol interval; thus, large irreducible error floors result if the Doppler frequency shift (DFS) is not estimated and subtracted.

In the work [44], the authors propose a state-space based receiver for M-DPSK signals in transmissions affected by fast fading and DFS, which evaluates the multiplicative distortion (amplitude and phase) of the baseband signal and uses those estimates to track the frequency offset. In addition, the proposed receiver can estimate the power of the line-of-sight component and the Rician fading parameter *K* which allow to monitor the transmission quality and control the transmitted power in adaptive systems.

Except for M-DPSK, the use of popular OFDM technique for high mobility LEO satellite channel is given in [45]. The work [45] utilizes the OFDM system for high-Doppler shift LEO satellite communication, a channel estimation algorithm by Kalman filtering based on comb-type pilot subcarriers is proposed in this paper. Due to the statistical characteristics of LEO channel, an OFDM system model on the frequency domain is derived and the correlation of the process noises in Kalman filtering between two consecutive identical signals at the same pilot subcarrier are modeled as the first Markov chain. The performance of the proposed method is compared with LS (Lease Square) channel estimator by measuring Bit Error Rate (BER) with QPSK, BPSK, 8-PSK and 16QAM as modulation schemes. The effectiveness of the proposed algorithm can be verified through the simulation results given in it.

In addition to [44] and [45], [46] propose a new channel estimation algorithm for low earth orbit satellite digital communications. Low earth orbit satellite channels impart severe spreading in delay and Doppler on the transmitted signal. The authors in [46] presented a new on-line algorithm for estimating the satellite channel in order to aid equalization and detection at the receiver. The technique estimates the parameters of the delay and Doppler spread channel and also the channel mean. This algorithm is also verified for a variety of scenarios including shadowing and during errors in receiver synchronization. The key block used in [46] is a coupled Kalman filter and AR parameter estimator. We replot it in Figure 7.

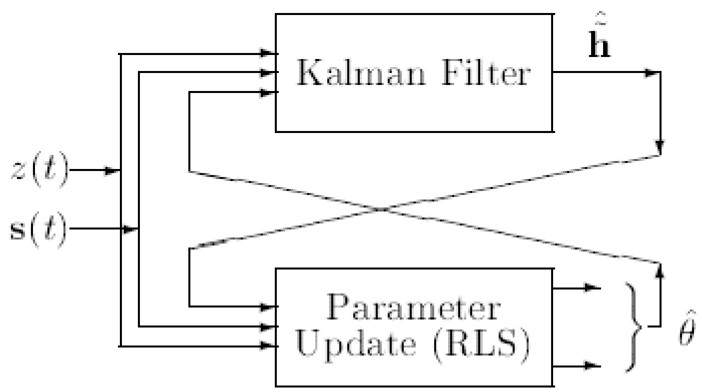


Figure 7 Coupled Kalman filter and AR parameter estimator [46].

Neural network (NN) is also a possible solution for channel estimation. In [47], neural network based channel estimation method is proposed for identifying the parameters of a nonlinear time varying satellite channel. A multipath time-varying Ricean-fading channel is considered in the analysis for a downlink scenarios. To study the flexibility and performance of the proposed method, the channel in question has been varied over a reasonable range of Doppler frequencies, and the estimation for each case has been made by employing 16 quadradture amplitude modulation (16-QAM) technique. Both back propagation (BP) and natural gradient (NG) algorithms have been studied for the channel identification technique. A NN maximum likelihood sequence estimator (NN-MLSE) based receiver has been studied for the addressed system. Simulation results show that the NN-MLSE receiver performs close to that of the ideal MLSE receiver in terms of symbol error rate. The NN-based channel estimator is shown in Figure 8.

The effect of non-ideal synchronization may impact the behavior of channel estimator. A tentative evaluation under this effect is given in [48].

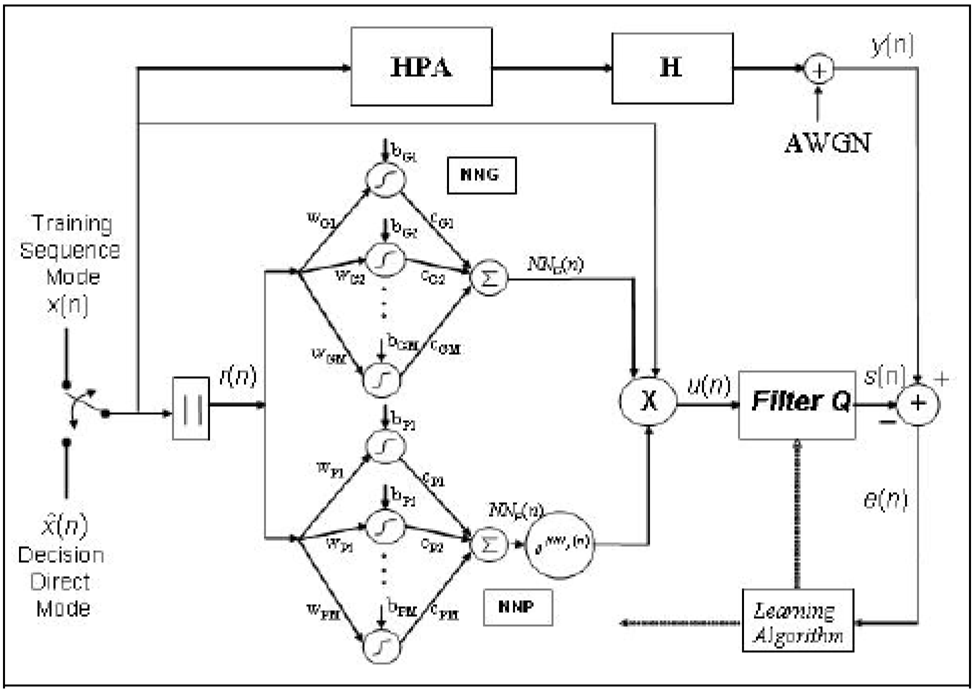


Figure 8 Neural network based channel estimator [47].

F) High Speed Demodulation and Data Acquisition

Since dynamic characteristics of LEO satellites will induce Doppler shift on carrier frequency. Most implementations of traditional receivers for LEO satellites adopt differential demodulation techniques, and the cost is a 3 dB demodulation threshold increment, which raises overall system budget and brings about constraints on practical implementations. The work [49] presents a new coherent demodulation method based on Dual Lock Loops aiming at large Doppler frequency shift, the variation rate of Doppler frequency shift in LEO satellite communication systems. Block diagram of dual lock loops are represented in Figure 9.

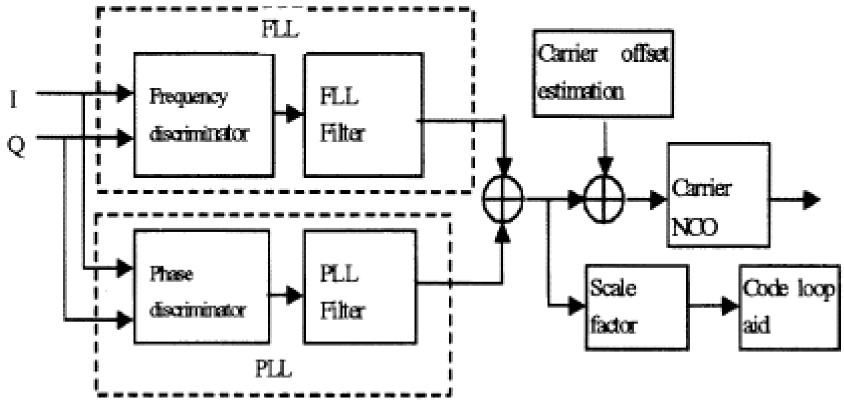


Figure 9 Block diagram of DuLL carrier tracking loop [49].

For the impact of a large Doppler frequency shift on the system performance over a LEO satellite communication system, the authors in [50] analyze the performance for a group of modulation schemes for an in-depth performance comparison. For a dual channel demodulation, it is a good reference to refer [51]. The block diagram of CDMA with dual-channel demodulator is shown in Figure 10.

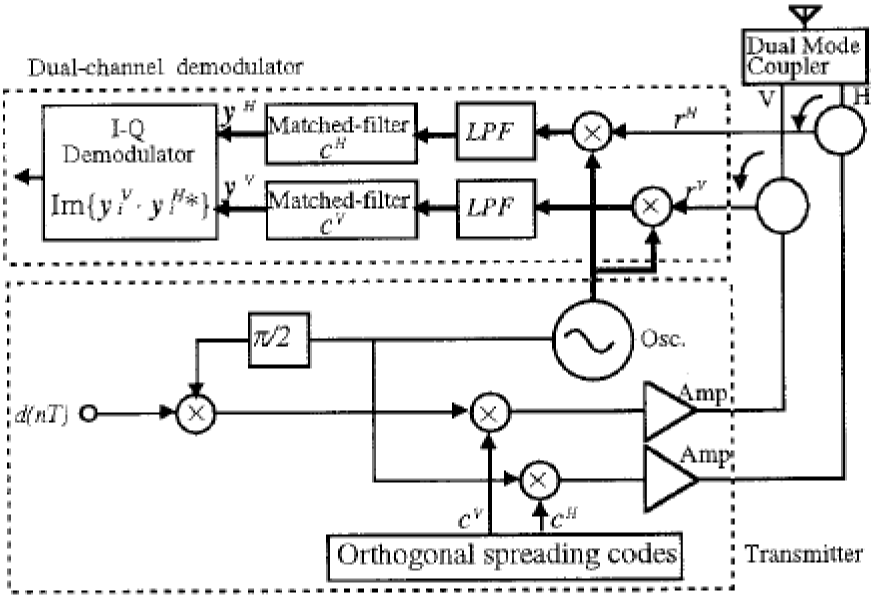


Figure 10 Block diagram of dual-channel demodulator [51].

Successful demodulation is the immediate goal of high speed data acquisition. However, there exist further steps to ensure correctness, including scrambling and error correcting codes.

In telecommunications and recording, a scrambler (often erroneously referred to as a randomizer) is a device that manipulates a data stream before transmitting. The manipulations are reversed by a descrambler at the receiving side. Scrambling is widely used in satellite, radio relay communications and PSTN modems. A scrambler can be placed just before a FEC coder, or it can be placed after the FEC, just before the modulation or line code. A scrambler here has nothing to do with encrypting, as the intent is not to render the message unintelligible, but to give the transmitted data useful engineering properties.

A scrambler replaces sequences into other sequences without removing undesirable sequences, and as a result it changes the probability of occurrence of vexatious sequences. Clearly it is not foolproof as there are input sequences that yield all-zeros, all-ones, or other undesirable periodic output sequences. A scrambler is therefore not a good substitute for a line code, which, through a coding step, removes unwanted sequences.

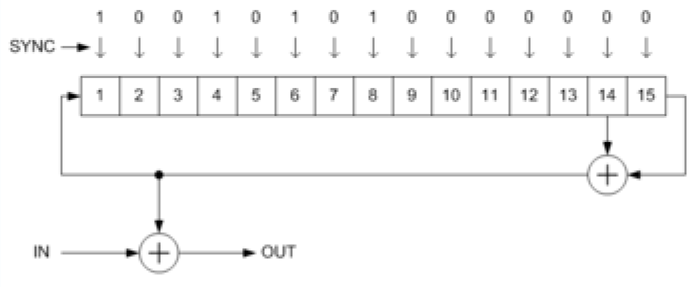
There are two main reasons why scrambling is used:

- It facilitates the work of a timing recovery circuit, an automatic gain control and other adaptive circuits of the receiver (eliminating long sequences consisting of '0' or '1' only).
- It eliminates the dependence of a signal's power spectrum upon the actual transmitted data, making it more dispersed to meet maximum power spectral density requirements (because if the power is concentrated in a narrow frequency band, it can interfere with adjacent channels due to the cross modulation and the intermodulation caused by non-linearities of the receiving tract).

Two types of scrambler:

Additive (synchronous) scramblers

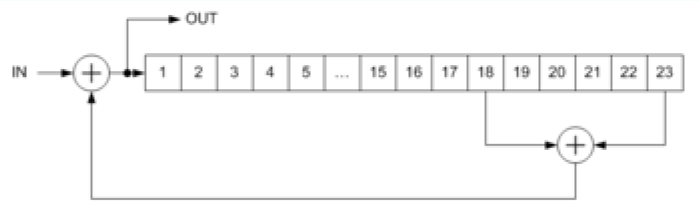
Additive scramblers (they are also referred to as *synchronous*) transform the input data stream by applying a pseudo-random binary sequence (PRBS) (by modulo-two addition). Sometimes a pre-calculated PRBS stored in the read-only memory is used, but more often it is generated by a linear feedback shift register (LFSR). The *additive descrambler* is just the same device as the additive scrambler. Additive scrambler/descrambler is defined by the polynomial of its LFSR (for the scrambler on in figure 1, $1 + x^{14} + x^{15}$) and its *initial state*. In order to assure a synchronous operation of the transmitting and receiving LFSR (that is, *scrambler* and *descrambler*), a *sync-word* must be used. A sync-word is a pattern that is placed in the data stream through equal intervals (that is, in each frame). A receiver searches for a few sync-words in adjacent frames and hence determines the place when its LFSR must be reloaded with a pre-defined *initial state*.



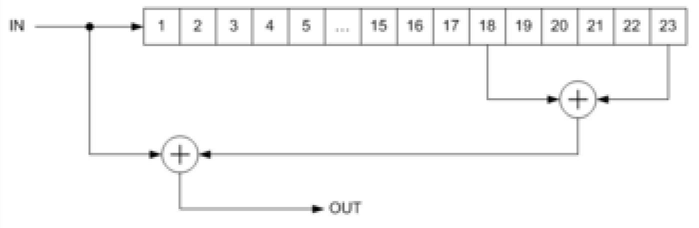
An additive scrambler (descrambler) used in DVB

Multiplicative (self-synchronizing) scramblers

Multiplicative scramblers are called so because they perform a *multiplication* of the input signal by the scrambler's transfer function in Z-space. They are discrete linear time-invariant systems. A multiplicative scrambler is recursive and a multiplicative descrambler is non-recursive. Unlike additive scramblers, multiplicative scramblers do not need the frame synchronization, that is why they are also called *self-synchronizing*. Multiplicative scrambler/descrambler is defined similarly by a polynomial (for the scrambler in figure 2, it is $1 + x^{18} + x^{23}$), which is also a *transfer function* of the descrambler.



A multiplicative scrambler used in V.34 recommendation



A multiplicative descrambler used in V.34 recommendation

G)FEC and Reed-Solomon Decoder

Combining forward-error correcting code with modulation may also be applied to satellite communication channel. In [52], a multilevel concatenated-coded M-DPSK modulation schemes for the shadowed mobile satellite communication channel is proposed. This paper presents a bandwidth-efficient multilevel concatenated-coded modulation scheme for reliable data transmission over the shadowed mobile satellite communication channel. In this scheme, bandwidth-efficient block modulation codes are used as the inner codes, and Reed-Solomon codes of various error correcting capabilities are used as the outer codes. The inner and outer codes are concatenated in multiple levels.

A general method for constructing multilevel concatenated modulation codes is presented, and a multistate closest coset decoding for these codes is proposed. Specific multilevel concatenated 8-PSK modulation codes have been constructed. These codes are designed to lower the bit error rate (BER) of the error floor caused by the large Doppler frequency shift due to the motion of vehicles. Simulation results show that these codes perform very well and achieve large coding gains over the uncoded reference modulation systems. The system diagram of this idea is shown in Figure 11.

Examples that uses coded modulation for transmission in a satellite communication channel can also be found in [53]-[55]. In [53], convolutionally interleaved PSK and DPSK trellis codes for satellite communication channels are discussed. Using PSK as modulation technique and using Trellis codes for transmission in satellite channels are discussed in literatures [54]-[55].

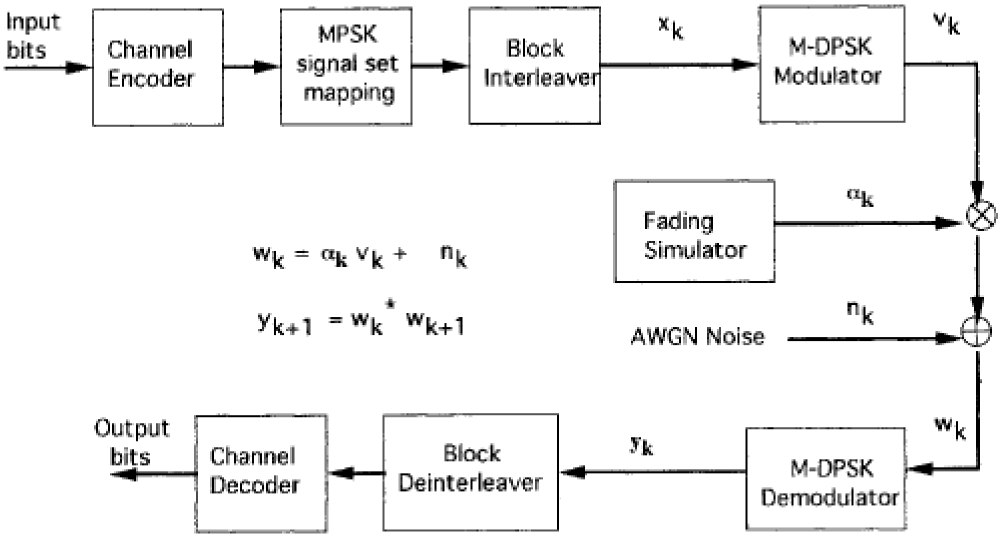


Figure 11 MDPSK-coded modulation system model for fast-fading Rician channel[52].

One of the key challenging block diagrams at the baseband receiver is Reed-Solomon decoder. Reed-Solomon codes are nonbinary cyclic codes with symbols made up of m-bit sequences, where m is any positive integer having a value greater than 2. R-S (n, k) codes on m-bit symbols exist for all n and k for which

$$0 \le k \le n \le 2^m + 2$$

where k is the number of data symbols being encoded, and n is the total number of code symbols in the encoded block. For the most conventional R-S (n, k) code,

$$(n,k) = (2^m - 1, 2^m - 1 - 2t)$$

where t is the symbol-error correcting capability of the code, and n - k = 2t is the number of parity symbols. An extended R-S code can be made up with n = 2^m or n = $2^m + 1$, but not any further.

Reed-Solomon codes achieve the largest possible code minimum distance for any linear code with the same encoder input and output block lengths. For nonbinary codes, the distance between two codewords is defined (analogous to Hamming distance) as the number of symbols in which the sequences differ. For Reed-Solomon codes, the code minimum distance is given by dmin = n - k + 1 (3)

The code is capable of correcting any combination of t or fewer errors, where t can be expressed as

$$t = \left\lfloor \frac{d\min - 1}{2} \right\rfloor = \left\lfloor \frac{n-k}{2} \right\rfloor$$

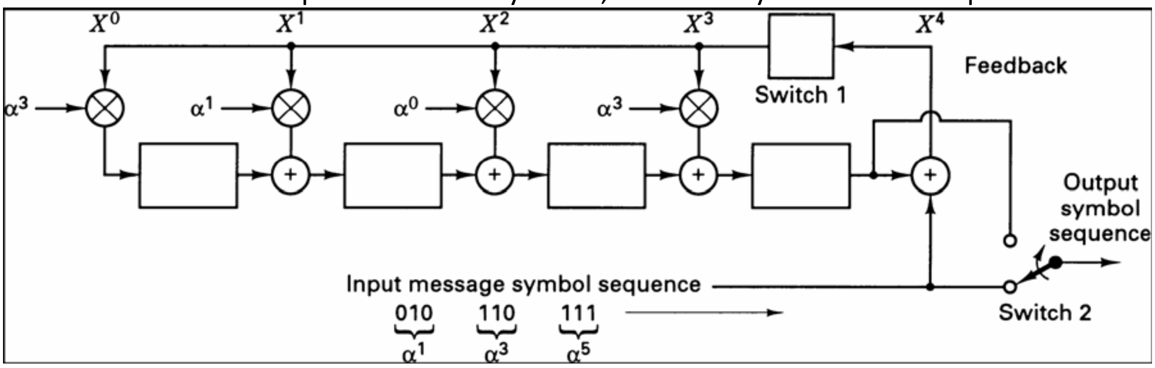
where $\lfloor x \rfloor$ means the largest integer not to exceed x.

RS encoding and encoding in systematic form can be summarized as follows. Consider RS codes with symbols from $GF(2^m)$, and let α be a primitive element in $GF(2^m)$ The generator polynomial of a primitive *t*-error correcting RS code of length is $2^m - 1$. Let $a(x) = a_0 + a_1 x + a_2 x^2 + ... + a_{k-1} x^{k-1}$ be the message to be encoded, *k*=*n*-2*t*.

The 2*t* parity-check digits are the coefficients of the remainder $b(x) = b_0 + b_1 x + b_2 x^2 + ... + b_{2t-1} x^{2t-1}$ resulting from dividing the message polynomial $x^{2t} a(x)$ by the generator polynomial $g(x)$.

We take a simple RS code for example. Using circuitry to encode a three-symbol sequence in systematic form with the (7, 3) R-S code described by g(X) requires the implementation of a linear feedback shift register (LFSR) circuit, as shown in following figure. It can easily be verified that the multiplier terms in it, taken from left to right, correspond to the coefficients of the polynomial (low order to high order).

This encoding process is the nonbinary equivalent of cyclic encoding. Here, the (7, 3) R-S nonzero codewords are made up of 2m - 1 = 7 symbols, and each symbol is made up of m = 3 bits.



However, this LFSR circuit might not be enough for hardware requirement. Based on the demand of application, high throughput is necessary for encoder design. According to our last work on BCH encoder, we follow the reference paper [6] and parallelize the hardware design in 8 times. The trade between throughput and gate counts is worth and cost only 2K gates for our BCH encoder, that is double the gates of original single-in-single-out LFSR circuit. Here, the difference between RS and BCH codes is symbol-based and bit-based.

The most popular decoding for hardware is modified Euclidean algorithm. Besides, Berlekamp algorithm is recently taken into account. We introduce modified Euclidean algorithm (MEA) here.

The decoding procedure of the RS code consists mainly of the following four steps:

Step 1: Syndrome calculation

The syndrome components can be obtained by evaluating r(x) at the root α^i, as shown in expression.

$$S_i = r(\alpha^i) = \sum_{j=0}^{n-1} r_j \alpha^{ij}, 1 \le i \le 2t$$

If all the syndrome components are equal to zero, the received vector is a codeword, otherwise errors occurred in the received codeword.

Step 2: Solving the key equation

This step is to solve the following key equation for calculating the error location and magnitude.

$$S(x) \cdot \sigma(x) = \omega(x) \bmod x^{n-k}$$

where S(x) is the syndrome polynomial, $\sigma(x)$ is the error locator polynomial, and $\omega(x)$ is the error evaluator polynomial. MEA is developed in order to avoid division computation in Euclidean algorithm.

Step 3: Finding the error locations

The roots of the error location polynomial are the inverse of error locations. To find the roots, either looking up values table or Chien search can be utilized.

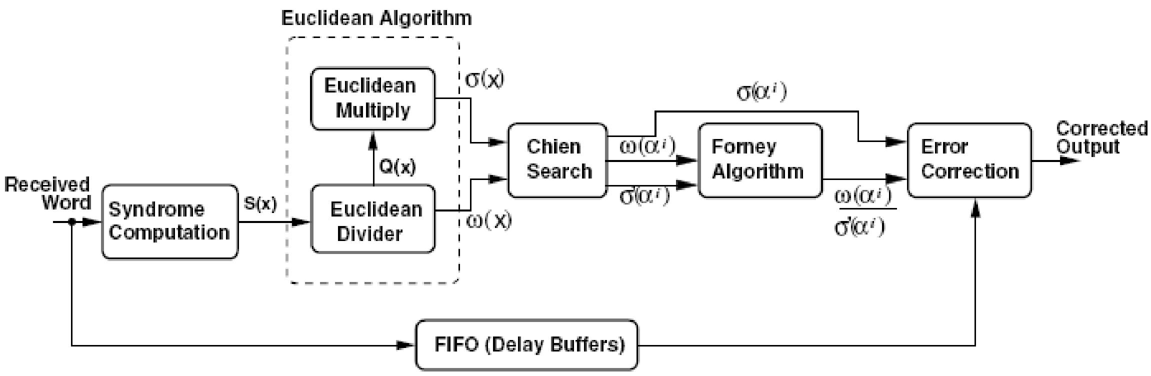
Step 4: Computing error values and error correction

The error value can be calculated with error evaluator polynomial $\omega(x)$ and $\sigma'(x)$, the derivation of $\sigma(x)$, at error position by Forney algorithm.

$$e_i = \frac{\omega(\alpha^{-i})}{\sigma(\alpha^{-i})} = \frac{\omega(\alpha^{-i})}{\sigma_{odd}(\alpha^{-i})}, i = 0,1,\ldots,n-1$$

where $\sigma_{odd}(\alpha^{-i})$ is the sum of odd terms of $\sigma(\alpha^{-i})$

The estimate of the original code vectors can be obtained by subtracting the error patterns from the received one.



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四、研究方法及進行步驟：（其中研究方法請詳細說明(1)採用之方法，(2)採用本方法之原因，(3)預計可能遭遇之困難及解決途徑，(4)重要儀器之配合使用情形，(5)一年以上之計畫請分年列述。）

研究方法：

(1) 採用之方法

(2) 採用本方法之原因：

(3) 預計可能遭遇之困難與解決途徑：

(4) 重要儀器之配合使用情形：

In this 12-month study to design this special-purpose LEO satellite communication receiver, our goal is to complete the baseband system design and system simulations based on the floating-point MATLAB codes. There will be several milestones to execute this project:

(i) Work with NSPO to complete system parameters and requirements among the entire satellite system blocks.
(ii) Develop satellite communication receiver architecture and system block diagram with interfaces
(iii) Design algorithms to facilitate system block diagram
(iv) Conduct system simulations to verify the design
(v) Generate implementation specifications for future hardware/software realization and implementation suggestion

Above procedure follows PI's hand-on experience to develop satellite communication systems in the US (e.g. system design of mobile communications using LEO satellite, INMARSAT earth station receiver, INMARSAT terminal receiver, DVB-S receiver, etc.)

There are potential challenges that we can foresee at this moment to complete such a challenging task in this time frame.

- Difficulty to obtain foreign contractor original system specifications: We do expect to analyze the entire satellite system to complete this task. We wish to obtain communication baseband portion and our initial task would verify various interface to Mira board and their requirements.
- Channel modeling: Such satellite communication channel modeling lacks enough information in open literatures, and thus creates challenges for link calculations and simulations. It usually is a multi-million USD project to complete link calculations in designing any new satellite communication receiver. We shall, however, try our best to deliver a working environment for system simulations, including RF sub-system influence.
- Synchronization and channel estimation for fast fading in LEO communications: LEO satellite communication suffers well-known (also rare) fast fading due to tremendous Doppler shift caused by LEO satellite speed. Due to potential tracking error to significantly degrade signal quality to even worsen the receiver operating conditions, the design of robust but effective synchronization and channel estimation is a key of receiver. Here the synchronization includes frame synchronization, frequency offset estimation, frequency/phase tracking, timing recovery. The PI has extensive academic and industrial experience in this area and will lead the team to complete the task. Only successful synchronization can lead to straightforward descrambling and decoding.

As we pointed the challenge to track frequency/phase/timing under tremendous LEO satellite communications, the Figure 12 depicts the optimal framework invented by Gardner, which is not available in open literatures, in spite of being famous in synchronization research. The work was originally supported by European Space Agency and thus a report and a patent owned by European Space Agency, which is difficult to be known outside the world.

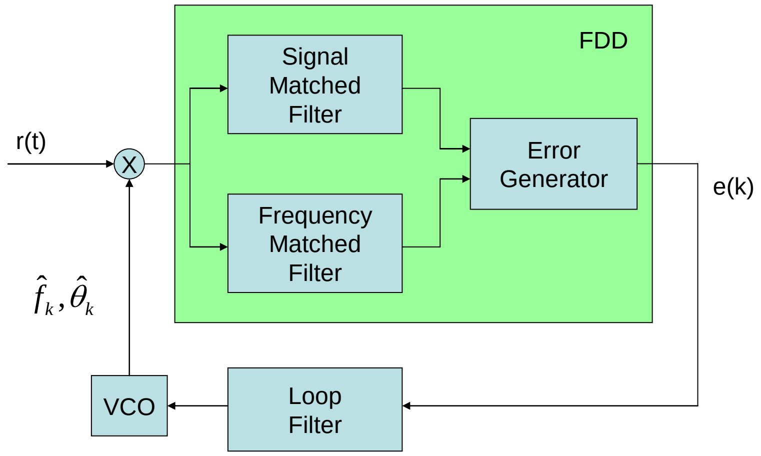


Figure 12 A Version of Optimal Synchronizer by Gardner

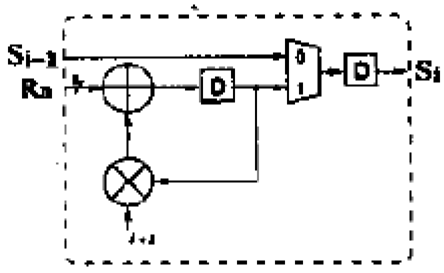
In our design, we plan to implement Gardner optimal synchronizer for LEO satellite communication receiver to recover frequency/phase from tremendous Doppler. The challenge lies in realization of Gardner optimal synchronizer. The most likely approach is through Messerschmidt's frequency rotator (published in 1979) to approximate optimal structure though DSP implementation is unknown in open literatures, or another realization is through PI's SCCL using a state-transition to approximate optimal structure (published in 1992) with an advantage of full DSP implementation.

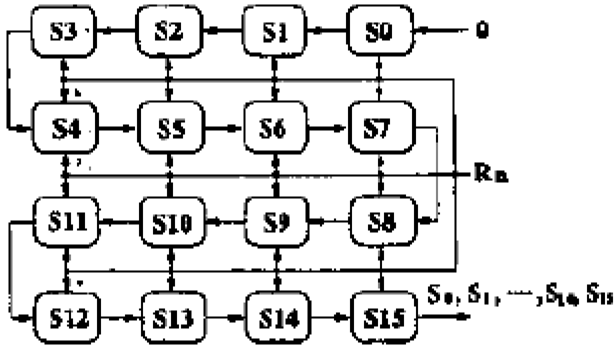
From above descriptions, we may note that our successful implementation of an effective synchronizer would be a critical key technology to LEO satellite communication receiver. As a matter of fact, without such capability in Taiwan's hands, the entire Formosa mission is under jeopardy facing nation's security treat.

Regarding RS decoder that might be one of the most challenging tasks in our design, RS decoder are divided into three blocks and they are syndrome computation block , modified Euclidean algorithm block, Chien search, Forney algorithm error correction blocks. Detail construction is as follow:

<u>Syndrome computation block</u>

The first step in the decoding algorithm is to calculate 2t syndromes Si, $0 \le i \le 2t$, which are used to correct correctable errors. If all 2t syndromes Si $0 \le i \le 2t$ are zero, then the received polynomial R(x) is a valid codeword C(x), that is, no errors have occurred. It evaluates the polynomial for 2t syndrome values and detects whether the evaluations are zero or non-zero. The partial syndrome is multiplied with α^i at each cycle and accumulated with the received symbol. This syndrome computation block renders it possible to compute the syndromes within symbol periods. The syndrome symbols $S_0, S_1, S_2, \ldots\ldots, S_{15}$ are output serially for solving a key equation





Modified Euclidean algorithm block

The ME algorithm is summarized as follows. Initially,

$$R_0(x) = x^{2t}, Q_0(x) = S(x), L_0(x) = 0, U_0(x) = 1$$

In i-th iteration,

(1) $R_i(x) = [\sigma_{i-1} b_{i-1} R_{i-1}(x) + \overline{\sigma}_{i-1} a_{i-1} Q_{i-1}(x)] - x^{|l_{i-1}|}[\overline{\sigma}_{i-1} a_{i-1} Q_{i-1}(x) + \sigma_{i-1} b_{i-1} R_{i-1}(x)]$

(2) $Q_i(x) = \sigma_{i-1} Q_{i-1}(x) + \overline{\sigma}_{i-1} R_{i-1}(x)$

(3) $L_i(x) = [\sigma_{i-1} b_{i-1} L_{i-1}(x) + \overline{\sigma}_{i-1}(x) a_{i-1} U_{i-1}(x)] - x^{|l_{i-1}|}[\sigma_{i-1} a_{i-1} U_{i-1}(x) + \overline{\sigma}_{i-1} b_{i-1} L_{i-1}(x)]$

(4) $U_i(x) = \sigma_{i-1} U_{i-1}(x) + \overline{\sigma}_{i-1} L_{i-1}(x)$

where a_{i-1} and b_{i-1} are the leading coefficients of $R_{i-1}(x)$ and $Q_{i-1}(x)$ respectively,

(5) $l_{i-1} = \deg(R_{i-1}(x)) - \deg(Q_{i-1}(x))$

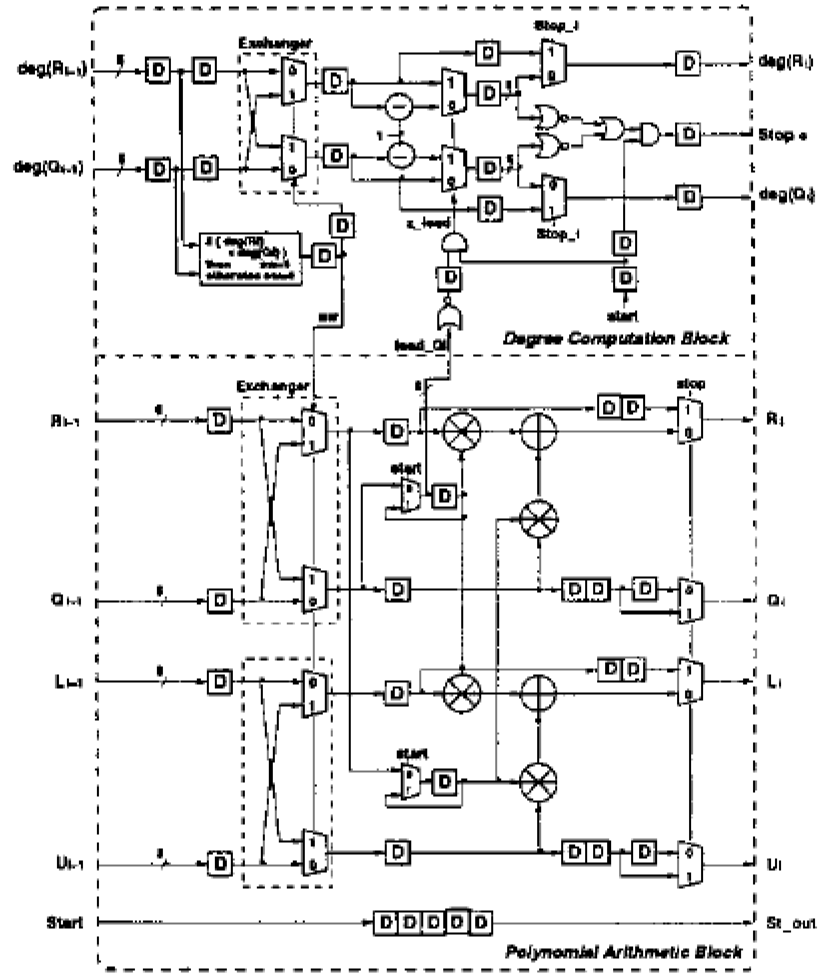
(6) $\sigma_{i-1} = \begin{cases} 1, l_{i-1} \geq 0 \\ 0, l_{i-1} < 0 \end{cases}$

The algorithm stops when $\deg(R_i(x)) < t$, where deg denote the degree of a ploynomial .

This detail hardware description is from [2].

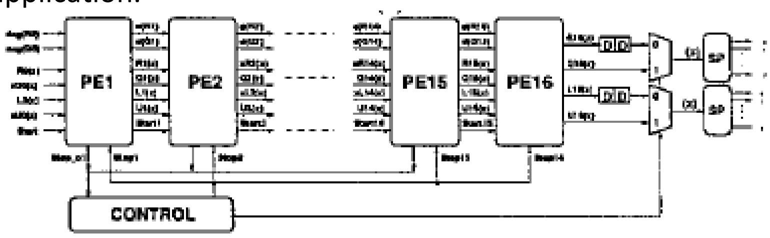
The ME algorithm Processing Element (PE) consists of a Degree Computation (DC) block and a Polynomial Arithmetic (PA) block.

The DC block processes several operations such as the degree computation, the degree update using subtraction and the leading zero detection in order to calculate the equations (5),(6)



First, it performs the control to determine when the polynomials of two systems are to be exchanged and when the initial polynomial and product polynomial are to be exchanged.

Thus, each exchange control circuit controls whether the first (Ri(x)) and second data lines (xQi(x)) are exchanged or not, and also control whether the third (Li(x)) and fourth data lines (xUi(x)) are exchanged or not. That is, exchange control circuit compute l_i = deg(Ri(x))- deg(Qi(x)). If deg(Ri(x)) < deg(Qi(x)), then the signal "SW" is asserted high (sw = 1), otherwise it is asserted low (sw = 0). Second, it detects if the arithmetic operation stop condition of (deg(w(x)) < deg(α(x))) or deg(Ri(x)) < t is satisfied. That is, if deg(R_{i+1}) < (t =)8 or deg(Q_{i+1}) < (t = 8), then stop.=l and computation stop, otherwise stop=0. A "start" signal is used to indicate the beginning of the polynomials, i.e.. the leading coefficients a_{i-1}, b_{i-1}. The "start" signal, as well as xQo(x) and xUo(x) is delayed by one time unit in such a manner that the leading coefficients properly initiated bv the start signal at the output of first PE(PE1). Signal "z_lead' has to be generated in order to check whether the leading coefficients of Qi(x) is equal to ''zero". 5-bits of arithmetic data are passed from DC block to DC block in ME algorithm processing block, and these data are used to generate multiplexer control signals "sw" and "stop" in each PE. The PA block processes finite-field multiplications and additions. This parallel architecture is set to 16 PE for high throughput concern. However, 16 PE may be reduced to 4 or 8, because 16 PE sometimes are oversized for some application.



Forney algorithm error correction blocks

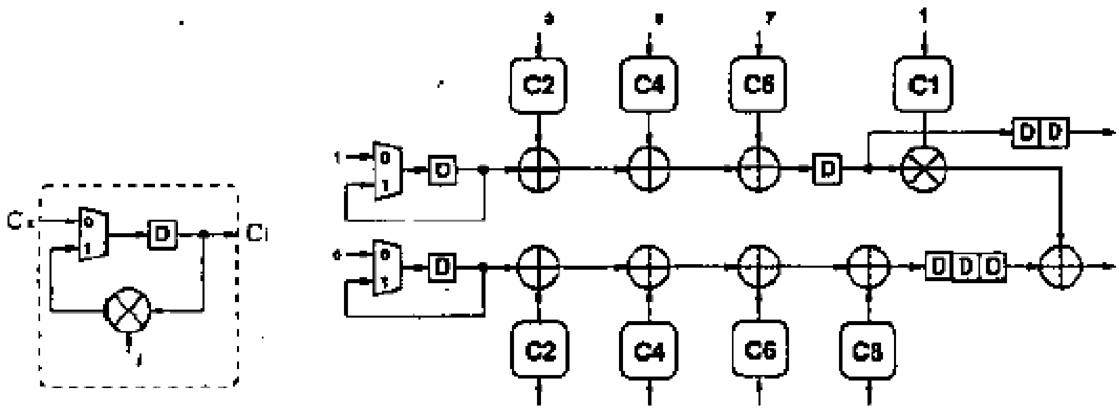
Let the error locator polynomial of degree n be defined by $\sigma(x) = x^t + \sigma_{t-1}x^{t-1} + ... + \sigma_0$

Then, finding the roots of such a polynomial can involve an extensive computation in an RS decoder. The Chien search algorithm is used to find the roots of an error locator polynomial. However, it requires the multiplication of each coefficient by the power of α, which is the root of a primitive irreducible polynomial of degree t over GF(2). The computation of error locations and value involves evaluating three polynomials $\sigma(\alpha^i), \omega(\alpha^i), \sigma'(\alpha^{-i})$

The circuit checks every element in the field and finds the roots as the solution.

$\sigma'(\alpha^i)$ would be eliminate by computing $\sigma_{odd}(x)$ and $\sigma_{even}(x)$

The finite-field adders accumulate the result of two Chien search cells, and send the sum to the next adder.



The block diagram of the Forney algorithm and error correction blocks which generate the error value and then the corrected symbol. For division of the Galois-field , first of all, the inverse element of the divisor is derived, and it is then multiplied with the element of the dividend by the pipelined fully-parallel multiplier. A straightforward approach for computation of the inverse of a nonzero element in GF(2^8) is to use a simple look-up table composed of 255 words of 8-bits, in which inverse of the field elements are stored. Consequently, it can be realized by means of a static ROM which gives a critical path delay less than that of pipelined multiplier.

Finally, to ensure our design being effective, good simulations through proper channel modeling would be another key as we stated earlier. It requires NSPO’s data about satellite communication channels to enhance our model meeting the true operating environments. To make the entire communication receiver working even better, earth station antenna control information with real-time feedback toward receiver and RF sub-system specifications would help a lot in channel estimation and prediction, which we may also need NSPO’s support.

To further ensure our design matching to NSPO system integration need, we have to work closely with NSPO, especially

- Interface to various boards (subsystems) for Foremosa-2 Mira Board
- ECL/LVDS interface to ensure successful ECL data acquisition
- Features of frame structure so that we can ensure appropriate frame-sync, de-scrambling, and decoding (especially RS decoder), and their feedback to check signal quality

五、預期完成之工作項目、具體成果及交付項目：(請列述在執行期限內預期完成之工作項目，如分 年進行，請分年列述。並請按計畫性質在研究成果方面加說明：(1)對於學術理論有何貢獻或對於太空科技及其他應用方面預期可獲何項效益？(2)參與工作人員，能得到何種訓練方面之獲益？)

(1) 預期完成之工作項目：
(2) 預期貢獻與效益：
(3) 工作人員所獲得之訓練：
(4) 交付項目：

The expected working outcomes include

(a) Study for system definition and specifications of LEO satellite receiver for Formosa-2
(b) Study of channel modeling
(c) Baseband receiver design of LEO satellite communications (floating-point)
  - ✓ Block diagram
  - ✓ Specifications related to each block
  - ✓ Reed-Solomon decoder implementation
  - ✓ Interfaces
(d) Study of the LEO satellite communication receiver
(e) Integrated simulations and verification of the baseband receiver design (floating-point simulations)
(f) Evaluation report to hardware board implementation and suggestion

The expected outcome can serve as the design specification for future real implementation in hardware and software, so that this project plays a key milestone of Taiwan's owning LEO satellite communication receiver. In spite of great success for NSPO in the past, capability to secure satellite communication links to deliver vital information from satellite to earth station is critical to Formosa-3, especially under nation's security treat. This project can establish the foundation of Taiwan's satellite communication system technology.

The participants (student and a full-time engineer) obtain rare opportunities to design and to implement LEO satellite receiver, which is foundation of modern digital (wireless) communications. This provides the shortest path toward own hardware and software of LEO satellite receiver. PI can also use this opportunity to pass his experience in satellite communications to participating students and engineers. We shall also look into different hardware methods (such as hardwired circuits, DSP,…) for future execution of hardware implementation, as an evaluation. (Note: PI has led students to implement OFDM in DSP, wireless comm. System in hardwired circuits, ..)

The deliverables of this project targeting at Formosa-II Mira Board include

(a) Major Interfaces including ECL/LVDS Interface, High rate acquisition and Time Code Interface
(b) Final report to summarize the receiver baseband design
  - (i) Principles of design with block diagram
  - (ii) Reed-Solomon Decoder design and verifications (software simulations codes, or hardware/FPGA verifications)
  - (iii) Frame synchronization and de-scrambling

六、預定進度甘特圖(Gantt Chart)：以為進度控制及檢討之依據。

計畫名稱：

月次 工作項目	第一月	第二月	第三月	第四月	第五月	第六月	第七月	第八月	第九月	第十月	第十一月	第十二月	備　註
System Spec. definition,	X	X	X	X									
Channel modeling	X	X	X										
RS Decoder			X	X	X	X	X	X					
Synchronication & de-scrambling				X	X	X	X	X					
Baseband design & interfaces				X	X	X	X	X	X				
MATLAB/C Codes					X	X	X	X	X	X			
Code integration &Simulations								X	X	X	X		
Final Report												X	
預定進度(累積數)	10%	20%	28%	35%	45%	50%	60%	70%	75%	85%	90%	100%	

說明：(1)工作項目請視計畫性質及需要自行訂定。預定進度以粗線表示其起訖日期，每月分三旬，如因其他受季節性限制之計畫必須配合一定之月份者，請在「月次」欄下註明實際月份，以利審查。

(2)預進度百分比一欄係為配合追蹤考核作業所需，累計百分比請視工作性質就以下因素擇一估計訂定：¬工作天數-經費分配®工作量比重¯擬達成目標之具體數字。

七、(一)人力配備：類別欄內請分別填寫「主持人」、「共同主持人」、「助理研究人員」等。(二)助理研究人員請檢附學經歷說明書。

類　　　別	姓　　　名	在本委託計畫內擔任之詳細具體工作性質、項目及範圍
主持人	陳光禎	System architect and project management
共同主持人	林茂昭	FEC decoder design and time code interface
助理研究人員	周泓甫	RS Decoder and FEC
助理研究人員	王易凡	ECL/LVDS Interface, High rate acquisition, time-code interface
助理研究人員	莊子由	De-scrambling, frame synchronization
助理研究人員	歐永俊	Channel modeling, interface to subsystems, integration simulation

格式8　　　　(如篇幅不足，請另紙繕附)　　　　第　　頁

（二）人事費用：本表填(1)主持人、共同主持人、協同主持人研究費，助理研究人員工作酬金及僱工工資，專任助理人事費申請額請以(月數+1.5)×月支酬金之所得數計列。(2)博士班研究生獎助金，亦請列入本表內。

姓　名	類　級　別	專或兼	在計畫內工作月數	月支酬金(元)	小計(元)
陳光禎	主持人	兼	12	8,000	96,000
林茂昭	協同主持人	兼	12	8,000	96,000
陳添輝	博士生研究助理	兼	12	8,000	96,000
鍾浩翔	博士生研究助理	兼	12	8,000	96,000
林祐瑜	碩士生研究助理	兼	12	6,000	72,000
莊子由	碩士生研究助理	兼	12	6,000	72,000
黃紀霖	碩士生研究助理	兼	12	6,000	72,000
總　計					600,000

格式9　　(如篇幅不足，請另紙繕附)　　第　　頁

八、(一)儀器設備配置：(1)如某項儀器設備必須添購而其單價在新台幣二十萬元以上者，請說明(A)計畫結束後之用途(B)教學及研究上之使用情形(C)指定由何單位保管維護，(2)「來源及數量」請填寫數字。如係「借用」或「租用」請在「備註」欄內註明向何單位借用或租用。

編號	儀器設備名稱(中英文併寫)	用途及說明	來源及數量				備註
			自有	借用	租用	添購	
	N/A						

格式10　　(如篇幅不足，請另紙繕附)　　第　　頁

(二)儀器設備費用：(1)「儀器設備名稱」欄請按儀器、機件、零件三類分別填寫，(2)表內「添置方式」，請在適當欄內打「V」號，(3)本處鼓勵自行設計製造儀器，如採自製方式，請檢附設計及製作方法，(4)單價在新台幣十萬元以上者，須檢附報價單。

儀器設備名稱	規格及廠牌	添置方式			價款				
		自製	國內採購	國外採購	單價		數量	總價	檢附報價單件數
(中英文併寫)					外幣	臺幣(元)		(臺幣元)	
	N/A								
共計									

格式11　　(如篇幅不足，請另紙繕附)　　第　　頁

九、其他相關費用：凡與研究計畫執行直接相關而不屬於上列各科目範圍之費用，包括文具、紙張、郵電費、印刷費、圖書費用、所需消耗性器材、國內差旅費用、維護費用、調查費、計算機使用費、儀器安裝、保險及運雜費等費用屬之。

項目名稱	用途及說明	金額	備註
文具紙張費	供購買文具用品及報表紙		
電腦耗材	購買碳粉匣，供資料儲存、備份		
資料檢索	供研究所需書籍、資訊		
影印印刷費	供印製論文、資料		
國內差旅費	供研究人員參加會議使用之交通費		
	Sub-total	5,000元	
電腦使用費	台大電算中心	20,000元	
總計		25,000元	

格式13　(如篇幅不足，請另紙繕附)　第　頁

十、國外差旅費：凡因執行計畫所需國外公差旅運費屬之(須詳填出國計畫內容)。

國外差旅費：

出差事由	出差地點	費用	備註
N/A			
總計			

格式14　　(如篇幅不足，請另紙繕附)　　第　頁

十一、貴重儀器使用費：（1)請逕洽國科會貴儀中心辦公室，瞭解使用貴重儀器之計費標準(2)請分別列明需使用國科會貴儀中心之儀器名稱及用途(3)依儀器計費標準不同，使用件數或時數欄可擇一填寫(4)本表供審查使用，請詳實估算貴重儀器使用費填列。

貴重儀器名稱	用　途　說　明	件數	時數	費用	備　註
N/A					
總　計					

格式16

十二、本計畫主持人/共同主持人/協同主持人近三年內曾參與之專題研究計畫

姓名：	□主持人 □共同主持人 □每人各填一份）		
計 畫 名 稱	計 畫 內 擔 任 工 作	起訖年月	補 助 機 構
民生網路之前瞻研究—子計劃六：多標準共同之可調無線介接與正交分頻(1/3)	主持人	94/08/01-95/07/31	行政院國家科學委員會
民生網路之前瞻研究—總計劃（I）	主持人	94/08/01-95/09/30	行政院國家科學委員會
民生網路之前瞻研究—總計劃(2/2)	主持人	95/08/01-96/07/31	行政院國家科學委員會
民生網路之前瞻研究—子計畫五：多標準共存之可調無線介接與正交分頻(1/2)	主持人	95/08/01-96/07/31	行政院國家科學委員會
歐盟科研架構計畫 個人可適性全球網路之可變組態多媒體網路終端技術(1/2)	主持人	95/09/01-97/11/30	行政院國家科學委員會
感知無線電為基礎的自主管理合作無線網路	主持人	96/08//1-98/07/31	行政院國家科學委員會

格式17

十五、國內從事相關領域之學者專家：

姓　　名	服務單位	職　　稱	地　　址	電話/傳真號碼

格式18

國 家 太 空 中 心
各類申請案申請人個人資料表
使　　用　　說　　明

一、適用範圍

凡申請本中心下列補助或獎助者均需檢附「個人資料表(正本或影本均可)。

(1) 專題研究計畫之主持人、共同主持人。(各八份)
(2) 研究獎助之申請人。(共八份)
(3) 國內外進修補助之申請人。(共八份)
(4) 博士後副研究員補助之申請人。(八份)
(5) 國內學人新任教學研究補助之申請人。(八份)
(6) 海外國人回國教學及研究補助之申請人。(八份)
(7) 國內專任教學及研究人員從事短期科技研究補助之申請人。(八份)
(8) 出席國際會議補助之申請人。(八份)

二、使用方法

(1) 本表包括五大項目：基本資料、學歷資料、現職與經歷、專長學科及學術著作目錄。
(2) 本表之每項資料，均將存人電腦，並列印寄予申請人保留，日後申請本會任何有關之獎助或補助，均可以此份電腦印就之報表影本代替原需之個人資料表。
(3) 為確保「個人資料表」之正確，若有任何異動，亦可利用此電腦印就之報表隨時更正後，影本擲還本會資訊中心以憑辦理，俟修正後將再寄上新表。

三、填表說明

1.基本資料

(1)「身分證統一編號」欄：本國籍請填身份證統一編號，外籍人士請填具永久性之身分證件號碼。
(2)「姓名」欄：請填中文姓名。
(3)「英文姓名」欄：請依Last Name, First Name 及 Middle Name之次序分開填寫。
(4)「國籍」欄：若為外籍人士請填護照所載國籍。
(5)「籍貫」欄：外籍人士不需填寫。
(6)「住宅地址」欄：請加填郵遞區號，若長住國外者請填國外住宅地址。
(7)「服務機關地址」欄：請填現職機關地址及郵遞區號，若目前尚在國外請填來臺服務機關地址。

2.主要學歷

(1) 請填大專以上之學歷，若無大專以上學歷者請填最高學歷即可。

(2) 「畢肄業學校」欄：請填畢(肄)業之學校，若屬外國學校請加填國名。

(3) 「學位」欄：若尚在求學階段請填「肄業」。

3.現職及經歷

(1) 兼任工作免填。

(2) 若有兩機構合聘者請註明。

(3) 請依任職之時間先後順序，由最近任職之經歷開始填起。

4.專長學科

請自行填寫與研究方向有關之專長學科。

5.著作目錄

(1) 請詳列個人最近五年內發表之學術性著作。

(2) 請將所有著作分成三大類：(A)Referred Paper,指在有專家審查的學術期刊已發表或已被接受之著作(尚未接受者，請勿列入)。(B)Conference Paper,指在學術會議發表論文。(C)Other Publication,包括專書、Technical Report、Patent等。

各類著作均請按發表時間先後順序排列：以英文發表者請用英文打字，以中文發表者請用中文打字或正楷書寫。

(3) 每篇文章請依作者姓名(按原出版之次序)、期刊年份、題目、期刊名稱、起訖頁數之順序填寫。

國家太空中心
各類申請案申請人個人資料表
使　用　說　明

填表日：_2008_/_09_/_30_

一、基本資料

身分證統一編號	T120318420						
姓　名	陳光禎		英 文 姓 名	Chen (Last Name)	Kwang (First Name)	Cheng (Middle Name)	
國　籍	台灣	籍貫	高雄	性別	■男　□女	出生日期	1961年09月25日
住宅地址	104台北市中山區基湖路122號					電話	(02)8501-2609
服務機關地址	10617台北市羅斯福路四段一號博理館514室					電話	(02)3366-3568

二、主要學歷

畢　業　學　校	國　別	科系所或主修學	學　位	起　訖　年　月
馬里蘭大學	美國	電機工程學系	博士	1987/09至1989/08
馬里蘭大學	美國	電機工程學系	碩士	1985/09至1987/08
國立台灣大學	臺灣	電機工程學系	學士	1979/09至1983/06

三、現職及與專長相關之經歷(按時間先後順序由最近經歷開始填起)

服　務　機　關	服　務　部　門	職　稱	起　訖　年　月
現職：			
台灣大學	電信工程學研究所	教授	1982/02-迄今
經歷：清華大學	電機工程系	教授	1996/08至1998/01
清華大學	電機工程系	副教授	1991/08至1996/07
IBM	研究部門	研究員	1989/10至1991/08
COMSAT	系統部門	資深工程師	1988/03至1989/09
Satellite System Engineering Inc.	國際部門	研究技術顧問	1987-07至1988/02

四、專長學科

1.無線通訊	2.寬頻網路	3.數位智財權管理	4.系統晶片架構

◎為了保護您的隱私，請詳閱下文，並簽選同意或不同意：

除身份證統一編號、出生日期、住宅地址及電話外，本人(同意、不同意)貴會得將本人個人資料提供給外界作為學術研究或掄才之用。

簽名：_____陳光禎______日期：___97.9.30____

填寫本表前，請詳閱本會各類申請案「申請人個人資料表使用說明」。

五、學術著作目錄(目錄編寫方法請見本表「使用說明」：若篇幅不足請附同尺寸之紙張繕寫，並編上頁數及姓名) 頁數：**3**

姓名： 陳光禎

Journal articles & book chapters:

1. C.C. Tseng, K.C. Chen, "Organizing Power Efficient Cluster-Based Network Architectures for Wireless Ad Hoc Networks," *Wireless Personal Communications*, Jan. 2008
2. S.M. Cheng, W.R. Lai, P. Lin, K.C. Chen, "Key Management for UMTS MBMS," *IEEE Transactions on Wireless Communications*, 2008
3. F.S. Chu, K.C. Chen, "Generalized Radio Resource Allocation for OFDMA Wireless Broadband Communications," *IEEE Transactions on Wireless Communications*, 2008
4. C.C. Tseng, H. T. Chen, and K.C. Chen, "Distribution of the Node Degree for Wireless Ad Hoc Networks in Shadow Fading Environments," *IEICE Trans. On Communications*, Vol.E90-B No.8, pp.2155-2158, Aug. 2007
5. P.W.Fu, K.C.Chen, "Rate, Sub-Carrier, and Power Allocations for Multi-Carrier CDMA with LMMSE Multiuser Detections," *IEEE Trans. on Wireless Communications*, Vol. 6, No.5, May 2007
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8. Huang Lee, K.C. Chen, "Performance Analysis and Improvement of De-correlating Detection for Multirate DS/CDMA," *IEEE Communications Letters*, Vol.9, No. 2, Feb. 2005
9. C.S. Chang, K.C. Chen, "Medium Access Protocol Design for Delay-Guaranteed Multicode CDMA Multimedia Networks," *IEEE Transactions on Wireless Communications*, Nov. 2003
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1. F.S. Chu, K.C. Chen, "Radio Resource Allocation for Mobile MIMO-OFDMA," *to appear in the Proceeding of IEEE VTC Spring*, Singapore, May 2008
2. C.K. Yu, K.C. Chen, "Multiple Systems Sensing for Cognitive Radio Networks over Rayleigh Fading Channel," *to appear in the Proceeding of IEEE VTC Spring*, Singapore, May 2008

3. S.Y. Lien, K.C. Chen, “Carrier Sensing based Multiple Access Protocols for Cognitive Radio Networks,” *to appear in the Proceeding IEEE International Conference on Communications*, Beijing, May 2008

4. K.C. Chen, et al., “Cognitive Radio Network Architecture: Part I – General Structure,” *to appear in the Proceeding of ACM International Conference on Ubiquitous In-formation Management and Communication*, Seoul, 2008

5. K.C. Chen, et al., “Cognitive Radio Network Architecture: Part II – Trusted Network Layer Structure,” *to appear in the Proceeding of ACM International Conference on Ubiquitous Information Management and Communication*, Seoul, 2008

6. K.C. Chen, L.H. Kung, David Shiung, R. Prasad, S. Chen, “Self-Organizing Terminal Architecture for Cognitive Radio Networks,” *Proceeding WPMC*, Jaipur, India, Dec. 2007

7. S.Y. Lien, C.C. Tseng, K.C. Chen, “Novel Rate-Distance Adaptation of Multiple Access Protocols in Cognitive Radio,” *Proc. IEEE PIMRC*, Athens, Greece, Sept. 2007

8. F.S. Chu, K.C. Chen, “Radio Resource Allocation in OFDMA Cognitive Radio Systems,” *Proc. IEEE PIMRC*, Athens, Greece, Sept. 2007

9. S.Y. Tu, K.C. Chen, “Spectrum Sensing of OFDMA Systems for Cognitive Radios,” *Proc. IEEE PIMRC*, Athens, Greece, Sept. 2007

10. C.C. Tseng, K.C. Chen, “Power Efficient Clustering Algorithm for (N,B)-Connected Wireless Ad Hoc Networks,” *Proc. IEEE ICC*, Glasgow, Scotland, Jun. 2007

11. C.C. Tseng, K.C. Chen, “Organizing Power Efficient Cluster-Based Network Architectures for Wireless Ad Hoc Networks,” *Proc. IEEE VTC Spring*, Dublin, Ireland, Apr. 2007

12. Y.C. Liao, K.C. Chen, “Multiuser Common Phase Error Estimation for Uplink OFDMA Communications,” *Proc. IEEE WCNC*, Hong Kong, Mar. 2007

13. Yi-Chen Chen, K.C. Chen, “Non-coherent Detection for SFH/BFSK Interfered by An Uncoordinated FH System,” *Proc. IEEE CCNC*, Las Vegas, USA, Jan. 2007

14. Feng-Seng Chu, Kwang-Cheng Chen, “Fair Adaptive Radio Resource Allocation of Mobile OFDMA,” *17th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC 2006*, Helsinki, Finland, 11-14, Sept. 2006

15. Yi-Chen Chen, Kwang-Cheng Chen, “Anti-jamming and Anti-multipath Performances of Generalized FHBFSK,” *IEEE VTC 2006 Fall*, Montreal, Canada, 25-28, Sept. 2006

16. Chih-Cheng Tseng, Hsuan-Tsang Chen, Kwang-Cheng Chen, “Characterizing The Wireless Ad Hoc Networks by Using The Distance Distributions,” *IST Mobile & Wireless Communications Summit 2006*, Mykonos, Greece, 4-8, Jun. 2006

17. Kin-Man Sun and Kwang-Cheng Chen, “Frequency Offset Estimation of TFI-OFDM in the Presence of Narrowband Interference,” *IST Mobile & Wireless Communications Summit 2006*, Mykonos, Greece, 4-8, Jun. 2006

18. Chih-Cheng Tseng; Hsuan-Tsang Chen; Kwang-Cheng Chen, "On The Distance Distributions of The Wireless Ad Hoc Networks," *IEEE VTC 2006 Spring*, Melbourne, Australia, 11-15, May 2006

19. Y.C. Liao, K.C. Chen, "Estimation of Wiener Phase Noise by the Autocorrelation of the ICI weighting Function in OFDM Systems," *Proc. 16th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC 2005*, Berlin, Germany, Sept. 2005

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23. Chao-Ming Chang, K.C. Chen, "Frequency Domain Orthogonal Multiuser Communication Systems over Frequency Selective Fading Channels," *IEEE VTC*, 2004

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2. C.K. Yu, Y.C. Liao, Y.H. Lin, K.C. Chen, "Phase Noise Estimation in OFDMA Uplink Communications," Wiley, 2008