HIGH ALPHABET FLIGHT TERMINATION SYSTEM

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ABSTRACT

This paper proposes a modification of the high alphabet method of data transmission over an RF carrier. The system maps eleven characters into three tones. The three tones are Frequency Modulated onto an RF carrier. The 165 unique characters can be utilized for data transmission. The advantages of this system are:

1. Longer duration data words which have narrow bandwidth yielding a high signal to noise ratio.
2. **D**igital **S**ignal **P**rocessing can be utilized to reconstruct characters from the tri-tone encoding.
3. The system will be less susceptible to external interference than normal **F**requency **S**hift **K**eying system. The majority of the three tone burst would have to masked in order to loose a data word.

KEY WORDS

Enhanced Flight Termination System (EFTS), Frequency Shift Keying, High Alphabet.

INTRODUCTION

In December of 2000 the Range Safety Council invited private industry to propose an Enhanced Flight Termination System (EFTS). The EFIS would be required to control a larger number of vehicles than the existing Flight Termination System and issue a larger number of commands than the existing Flight Termination System. One of CMC **E**lectronics-**C**incinnati's (CMCEC) proposal is an Enhanced High Alphabet system. The system proposed by CMCEC would be compatible with existing systems. The existing Flight Termination systems are FM based, and have 35 years of heritage. One system is tone based, where each unique tone combination represents a command. The other is High Alphabet which utilizes fewer orthogonal tone sets than the proposed system. Since both systems are FM based the proposed system would require the minimal changes the ground station or RF/IF chain in the vehicle.

ENHANCED HIGH ALHPABET FLIGHT TERMINATION SYSTEM

The basic concept of the enhanced high alphabet approach lies in the generation of an "alphabet" of characters (i.e. letters) from an orthogonal tone set. Given an available set of 11 orthogonal tones, a character consisting of any 3 tones results in a total of 165 possible tri-tone characters to form the alphabet (number of combinations of 11 items taken 3 at a time). A twelfth orthogonal tone will be utilized as a stand alone character and may be transmitted independently of the tri-tone characters. Each of the tri-tone characters may be uniquely mapped to a 7-bit data pattern (128 characters) with the remaining 92 characters available for other functions. Two special characters are assigned to represent a single bit, either a 0 bit or a I bit, from the remaining 92 unassigned characters. One of these two special characters would be transmitted at the beginning of a command frame according to the value of the first bit and would be used by the receiver for frame synchronization. Figure 1 is the block diagram of the

EFTS transmitter. The transmitter is located in the ground station. The ground station issues commands over the RF link to vehicles under its controls.

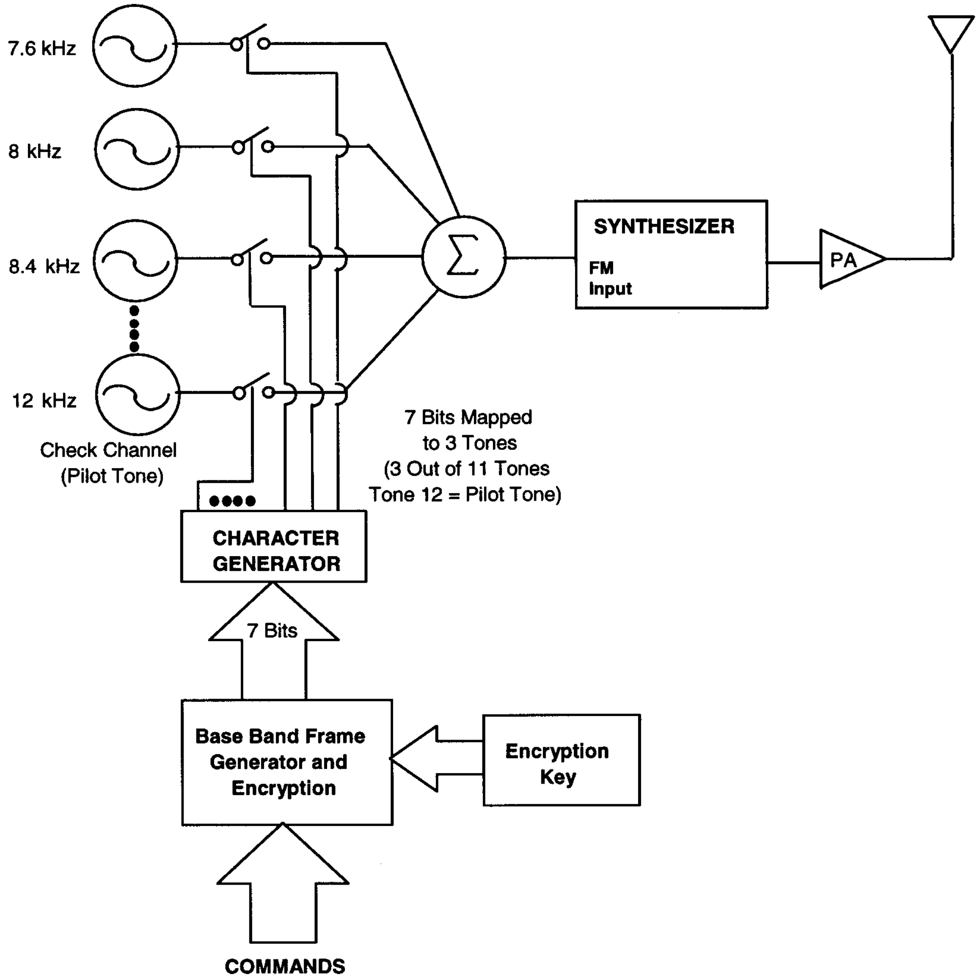


Figure 1: Enhanced Flight Termination System Transmitter

Figure 1-1 is a block diagram of the proposed EFTS ground station. The encoder would operate in any of the three modes. IRIG, High Alphabet (7 orthogonal tones), or Enhanced High Alphabet. The encoder would be the only change to the existing Flight Termination system hardware, this would minimize the expense of implementing the EFTS and maintain backward compatibility with existing formats. The encoder would accept commands as a system input, then depending on the format selected would provide the correct base band signal to the existing FM Exciter. The FM Exciter is a synthesizer cascaded with a driver amplifier. The output of the Exciter drives a High Power Amplifier (HPA) which is transmitted by the ground station antenna. The strength of the proposed system is the existing Exciter, HPA, and ground station antenna designs would not require changes.

Figure 2 is a block diagram of the EFTS receiver located in the vehicle under control of the ground station. To support Enhanced High Alphabet the existing RF/1F design of the receiver for all systems would not require any changes. Since the FM detection utilizes a discriminator and not a Phase Lock Loop (PLL) for demodulation the receiver is not subject to unlocking problems that can occur due to mechanical shock. Mechanical shock would induce a step change in frequency in the Voltage Controlled Oscillator (VCO) of the PLL. If the step change in frequency exceeds the hold in range of the of the PLL the signal would not be demodulated due to loss of lock condition. An FM discriminator would not require a finite time interval the reacquire the signal that is characteristic of a PLL.

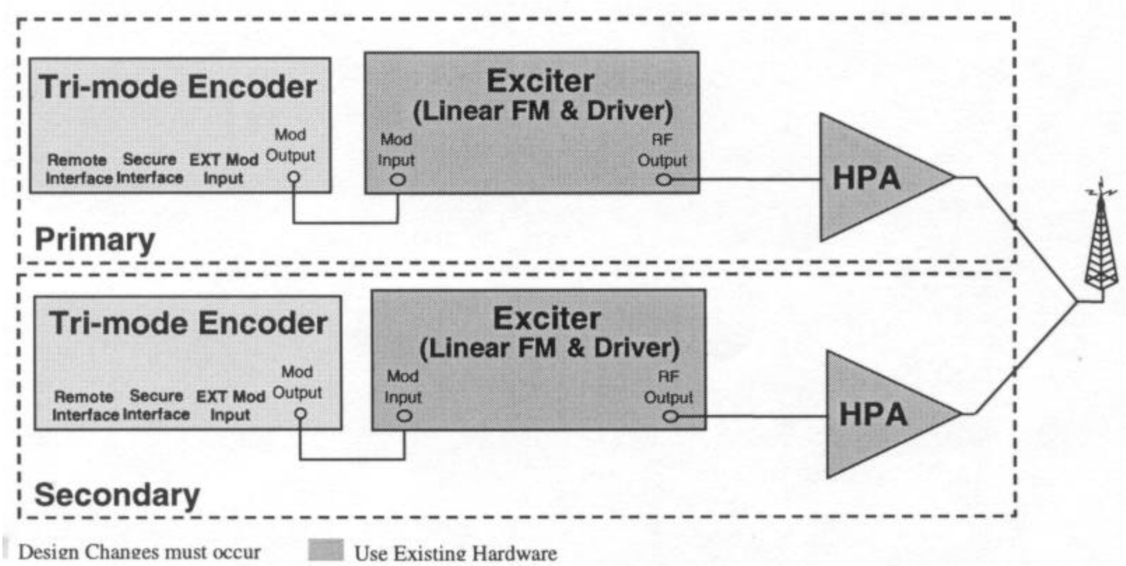


Figure 1-1 Block Diagram Of Existing System Modifications Required

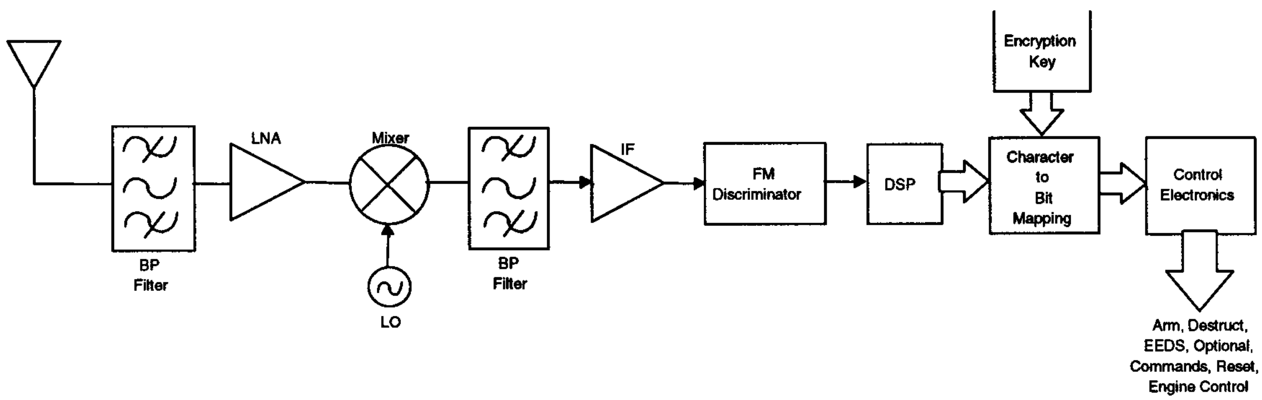


Figure 2: Enhanced Flight Termination System Receiver.

There is a 24-bit variable field plus a 40-bit fixed field. The 64-bit frame is compatible with the Data Encryption Standard (DES) and the Triple Data Encryption Algorithm (TDEA). The 40 bit fixed field is required for authentication.

As shown in Figure 3, the variable field is made up of a command field, command count field and an unassigned field, which may be used for optional functions and/or future capabilities. The fixed field is made up of a vehicle ID field, two range ID fields and an encryption sync field. The command field will utilize a (7,4) Hamming code for additional command error protection. The (7,4) Hamming code is capable of detecting a maximum of two bit errors and correcting up to one bit error within a command block. The command field allows for a maximum of 16 possible unique commands. The command count field is useful when the frame is being encrypted to provide a mechanism for updating the FTR to the ground station's command counter. Each time command string is transmitted the command count is incremented by one. The receiver compares the numerical value of the stored command count with the demodulated command count. If the command count of the demodulated signal is greater than the stored count the command then the command is valid. If the command count is less than the stored value the command is a non-valid.

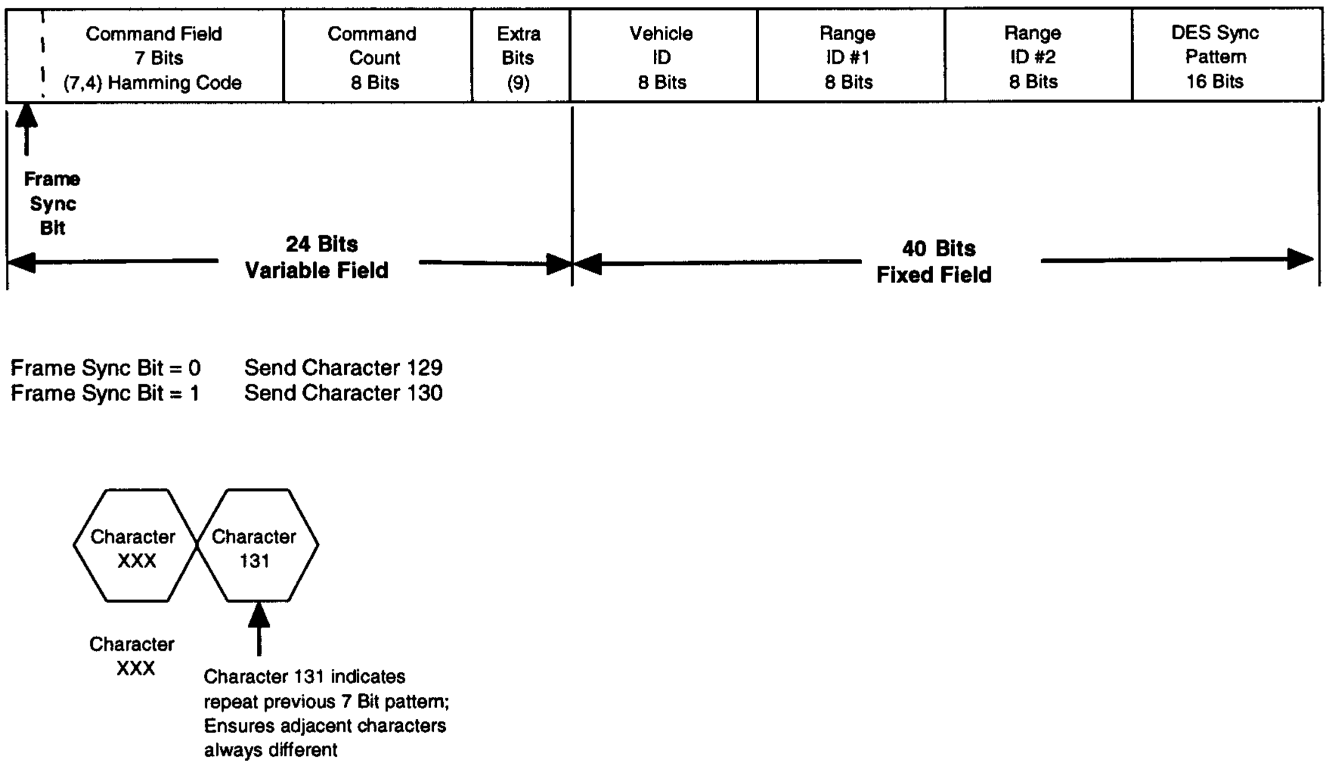


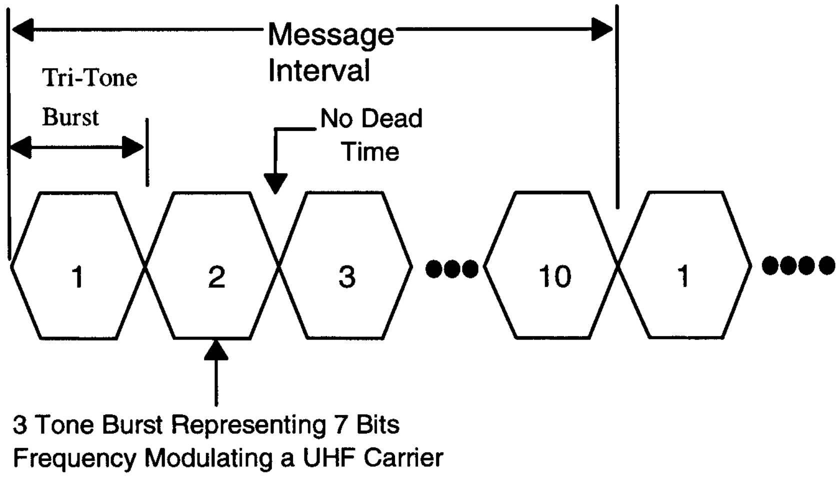
Figure 3 Base band message frame format for the High Alphabet based system.

Figure 4 represents a typical Base Band pattern if viewed in the time domain. Each burst consists of three orthogonal frequencies that Frequency Modulate an RF carrier. Keeping in mind that pilot tone will always be present, if two tones appear the burst would be rejected as a spurious signal. If four tones appear the signal will be rejected due to the presence of interference, provided significant noise immunity. Figure 5 is the Spectrum of a burst when all three tones are adjacent.

Post detection Digital Signal Processing would be utilized to identify the frequency of each tone. Knowing the frequencies of the tones, each burst would then be identified to one of the 165 characters it represents.

A large portion of the triple tone burst would have to be masked by an interfering signal for all information to be lost. The demodulated signal is digitized and stored in memory. This stored signal is processed by DSP. If three valid orthogonal tones are recognized the signal energy integrated over the time interval of the tones are present and numerical magnitude is stored. Non recognized signals are integrated and stored in the same memory location as noise. The threshold for signal detection, set in the DSP circuitry is the energy in the valid signal must exceed the energy of the “noise” signal by two to one, therefore an interfering signal would have to mask a valid signal for a time interval exceeding half of the tri-tone burst.

The enhanced high alphabet FTR is an analog self-synchronizing non-coherent system requiring no bit synchronization or clock recovery. However, as indicated in Figure 6, the worst case receiver cold start message acquisition time can be considered to occur at the end of the first complete received message frame. This worst case time will occur if the receiver does not detect the presence of a valid signal until immediately preceding a frame sync character. In this case, message processing would not occur until the following message frame containing a valid sync character was received.



Tone Frequencies Present In A Burst	Character Number
1,2,3	0
1,2,4	1
1,2,5	2
•	•
•	•
•	•
9,10,11	165

Figure 4 RF message frame seen in the time domain.

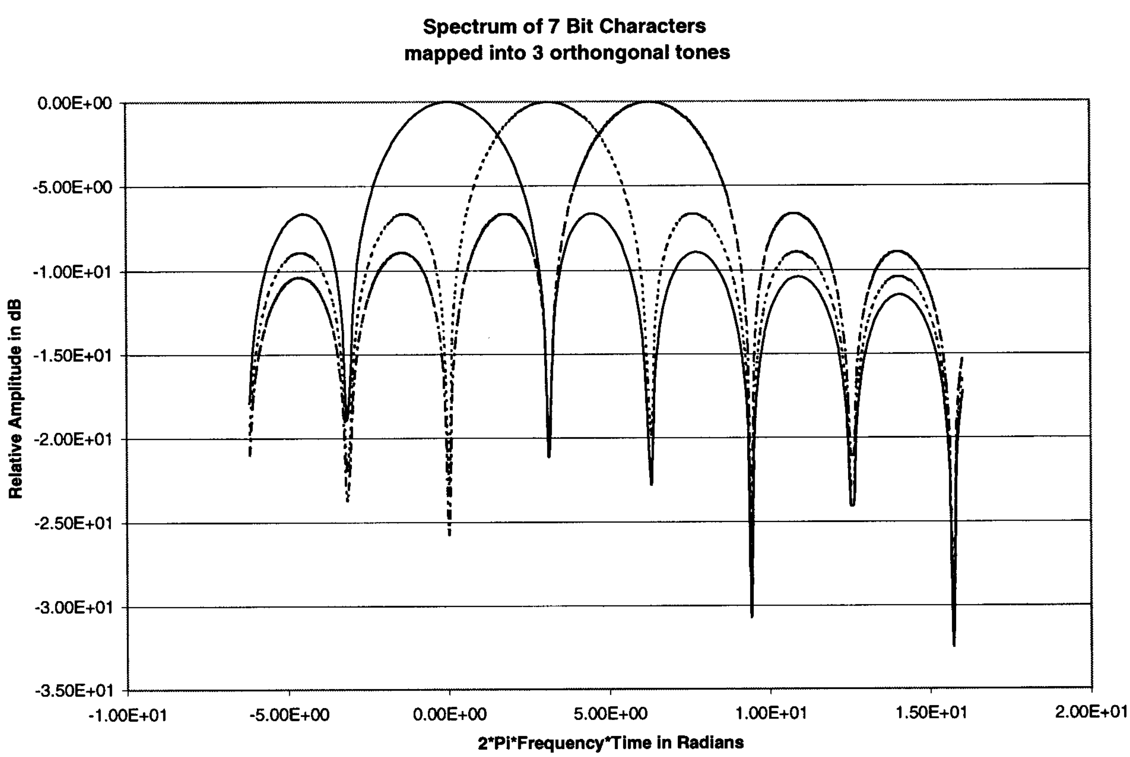


Figure 5 Normalized RF Spectrum of three adjacent tones

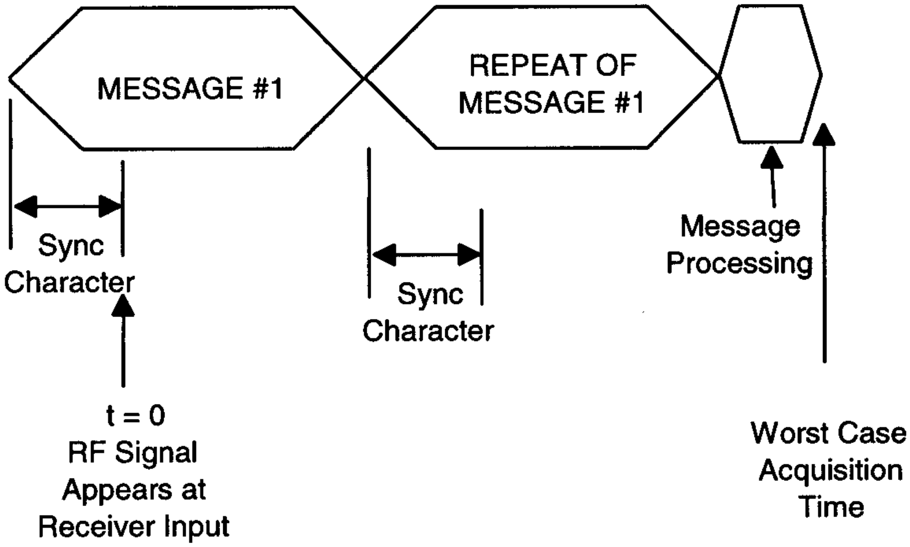


Figure 6 Worst Case Receiver Acquisition

Conclusion

The High Alphabet Enhanced Flight Termination System represents a possible high signal to noise, spectral efficient, low probability of interference approach to data transmission, and require minimum changes to the existing ground station equipment. Assuming a character length of 0.5 mSec the worst case acquisition time is 48.5 mSec.

References

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