AN IN-BAND FREQUENCY AGILITY MODEM IMPLEMENTED WITH A DSP DEVICE

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ABSTRACT

We present a modem with in-band frequency agility which has been implemented with the TMS 32010 signal processor. A strategy based on embedded real time channel estimation (RTCE) has been adopted to manage the frequency agility. It has the advantage of being able to combat frequency selective interferences, and it involves low handling complexity.

INTRODUCTION

Data transmission using high frequency (HF) radio has generally been restricted to low data rates, due to the properties of the transmission medium. For communication between any two points, the HF link suffers considerably from frequency selective fading, large doppler shift, and the various additive interferences. The additive noise effect and the frequency selective fading are considered to be more serious, and hence, a variety of methods have been proposed to decrease its influence on the data link performance in HF band.

There are methods that select a new HF link if the present one deteriorates. They are based on the detected interference spectra, and work with in-band frequency agility and channel coding [1]. Ahother approach uses in-band frequency diversity. Transmission band is divided into a number of subbands or subchannels, and a data stream is diversed over the subchannels. A modem with orthogonally multiplexed QAM signals was proposed by Hirosaki [2]. Adaptation to the time-varying channel can be a solution to the above problem. In fact, there are adaptive modems which are based on fast digital signal processors [3].

The method considered in this paper is based on the combination of the R.T.C.E. (Real Time Channel Estimation) and in-band frequency agility techniques. Modem concept is restricted to band-limited channels and sufficiently short times [4], and it is considered in the next section.

Functional specifications of the modem are considered in the modem implementation section. Two TMS 32010 signal processors can be used to perform the signal processing of either the modulator or the demodulator. The functions implemented in software by the signal processors are considered.

The work presented in this paper is directed at demonstrating the feasibility of implementing a modem at HF as is considered in the last sections.

MODEM CONCEPT

In this section the modem concept is depicted. The signal used to carry out the transmission is the addition of two signals: the data signal plus the sounding signal. The last one is used to explore the channel and to help the frequency agility. The sounding signal is modulated by a deterministic data stream known by the receiver. This signal consists of (see figure 1) a cyclic sequence divided into eight time intervals, each of which corresponding to one subcarrier of a set of eight. This set of frequencies goes through the vocal band (300-3000Hz), so that a channel sounding in reception can be performed.

When the subcarrier of the sounding signal is the same as the one of data, the first is not modulated.

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The subchannels into which the vocal channel is divided are 300 Hz wide, so that the rate chosen is 300 b.p.s. using a DPSK-2 scheme. One cycle of the sounding signal lasts about 267 ms, and each time interval is 33,33 ms long.

At this point it should be explained why these parameters have been chosen. First, the sounding should be carried out so that the channel can be considered stationary within that period of time. Second, it should allow to update the frequency chosen among the set of them within the shortest period of time. Third, it should give enough information to perform the R.T.C.E. in reception. Fourth, it should include the largest number of possible choices. The first requirement leads to a cycle time up to 300 ms [ref. 4]. Moreover, the interference can be considered frequency selective with a interference bandwidth of 300 Hz [ref. 5]. Finally, considering the vocal channel to be sounded, the parameters chosen give the best trade-off.

Figure 3 shows a result of a set of experiences carried out between Barcelona and Madrid. The horizontal axis represents frequencies, and the vertical one stands for signal power. It can be concluded from this figure that the interference level is really important only in a subchannel up to 300 Hz wide. In fact, in 95 % of cases it has been observed the same characteristic. Therefore, there is always or almost always an available subchannel to carry out the data transmission successfully. This experimental remark is useful as far as R.T.C.E. is concerned.

The frequency agility refers to the dynamic change of data signal subcarrier. Two purposes are to be reached here. First, the frequency agility should be performed without interrupting the data transmission. Second, this agility should not imply an increase in the b.e.r. It will be seen that, to reach there purposes the sounding signal is essential.

This paragraph describes the process of changing the subcarrier. First, the receiver requires a new subcarrier, which has been determined using R.T.C.E. techniques over the sounding signal, to the transmitter via a back channel. Then, the transmitter, upon reception of the new subcarrier, acknowledges sending an ACK signal to the receiver. There is a specific protocol designed to make this process reliable. After that, the transmitter waits until the sounding subcarrier is the same as the new recommended. When this is verified, the sounding signal is modulated by the data stream. As a result, a redundant signal is available in the channel. The signal is the addition of the new frequency and the present one both modulated by the data stream. So, a redundant time interval is sent to the channel (see figure 1). Within this interval, the change of data subcarrier is carrier out using the redundant information so as to avoid transitory effects. At the end of it, the data subcarrier is already the new recommended, and the sounding signal is modulated by a deterministic stream again. In figure 1 an example of change is given from f_4 to f_0. As it can be seen, there are two possible situations of the start of the changing process called "A" and "B". Situation "B" corresponds to the process already described. Situation "A" has a little difference. In this situation, the sounding subcarrier immediately coincides with the one recommended (f_0), but the entire redundant interval is not available to carry out the change. Therefore, a new redundant interval is awaited before starting the subcarrier change.

MODEM IMPLEMENTATION

The modem proposed has been implemented using the microprocessor TMS-32010 of Texas Instruments, so that it involves a low handling complexity.

Figure 2 shows the block diagram of the system configuration. The modulator is shown in the upper part of the figure. It has two main inputs: the data stream to be transmitted and the information concerning the subcarrier chosen by R.T.C.E. techniques in the receiver. A ROM source program provides the microprocessor with all the routines needed, such as encoder, DPSK-2 modulator, sounder and filters. The output of the microprocessor feds a D/A converter whose output is filtered by a low pass filter. Finally, the resulting signal feds the SSB transceiver to be H.F. radiated.

Under the part already described, the demodulator is shown starting at the low pass anti-aliasing filter. Its output feds and A/D converter whose 12-bit output is processed by the TMS-32010 according to the routines stored in the ROM source program. Some of them are the DPSK demodulator, filters, clock recovery routines and the R.T.C.E. routine, which selects the best subcarrier to transmit the data stream. The digital output port provides the demodulated data, a synchronization signal and the information related to the subcarrier chosen. This information is sent to the modulator by means of a back channel.

In this implementation, the TMS-32010 operates with a sampling frequency equal to 7200Hz, so that considering a rate of 300 b.p.s. 24 samples per bit are available.

RESULTS

In a wide research program experiences have been carried out between Madrid and Barcelona in order to measure the S/N ratio over different sub-bands of which a H.F. ionospheric channel is composed. These measures allow to test the reliability of the in-band adaptive system proposed.

The procedure chosen is the following described. And SSB signal, whose modulating signal is white gaussian noise, is transmitted so that its sprectrum is flat in the radiochannel band. This modulation has to be performed in a very short period of time, so that the radiochannel can be considered invariant in a period of time equal to two modulation periods. This is accomplished so as to compare the received signal with and without modulation upon equal channel conditions. The spectrum of the recived signal is calculated in the receiver, first over the modulated interval and then over the non-modulated one. Thus, it is possible to compare both spectrums and to calculate the ratio S/N of the different sub-bands so that the interference level can be determined.

During the period of time Sept-Nov of 1988 420 measures were carried out, taking the frequency 6.770MHz. They have revealed that it is possible to find, in more than the 95% of the sounding time, sub-channels 300Hz wide in the H.F. radiochannel whose ratio signal to perturbation guarantees a good quality of communication. As an example, figure 3 shows a result of the received signal power an interference power versus the subcarrier frequency used.

The reliability of the modem proposed relies on the fact that the perturbations present in the H.F. radiochannel studied are narrow-band perturbations. This is essential to carry out the frequency agility efficiently.

CONCLUSIONS

From the measures carried out two remarks are of interest. First, in channels 3KHz wide whose frequency is lower than the M.U.F. (Maximum Usable Frequency) it is possible to find sub-channels 300Hz wide showing a S/N ratio over a minimum predetermined to ensure the quality of a communication. Second, it has been found that the perturbations present in the radiochannel are frequency selective, i.e., it is possible to find sub-channels non-corrupted by these perturbations.

The remarks stated are important so as to demonstrate the feasibility of the modem proposed. In this way, it is clear that they are the basis for the frequency agility based on R.T.C.E. techniques. On the other hand, the probability of error in reception is nowadays being measured in another set of experiences between Barcelona and Madrid to determine the modem performance. Finally, it should be stressed that the modem implementation represents a low complexity using the microprocessor TMS-32010.

ACKNOWLEDGEMENT

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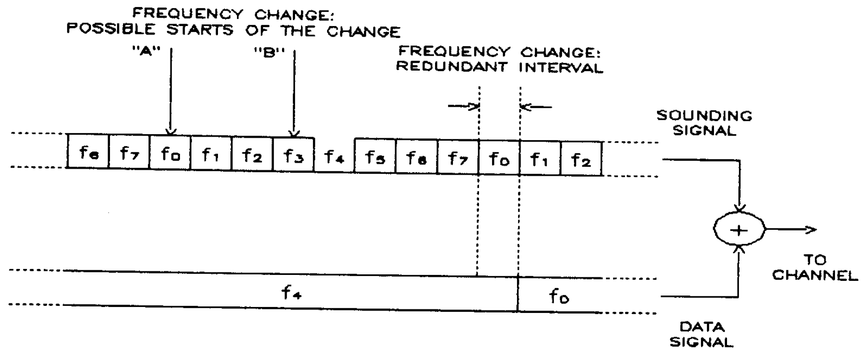

Fig. 1 Time diagram of the signal used

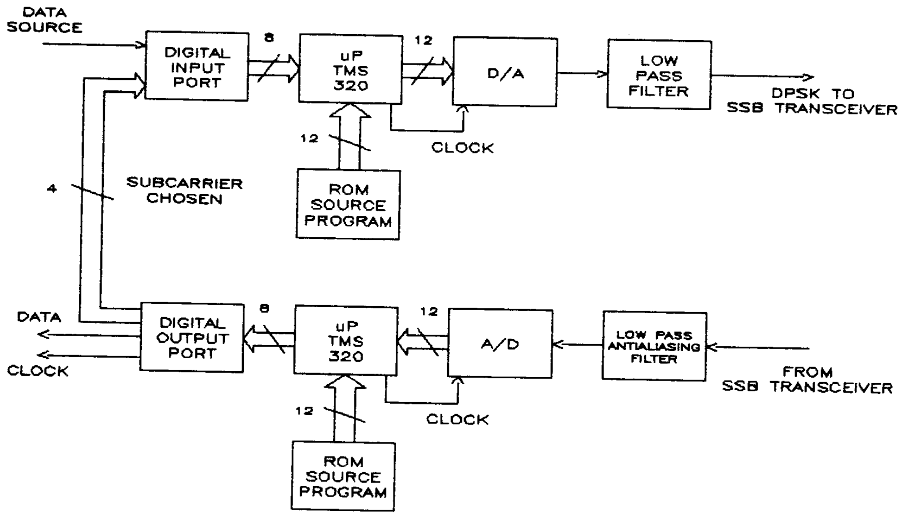

Fig. 2 System Configuration

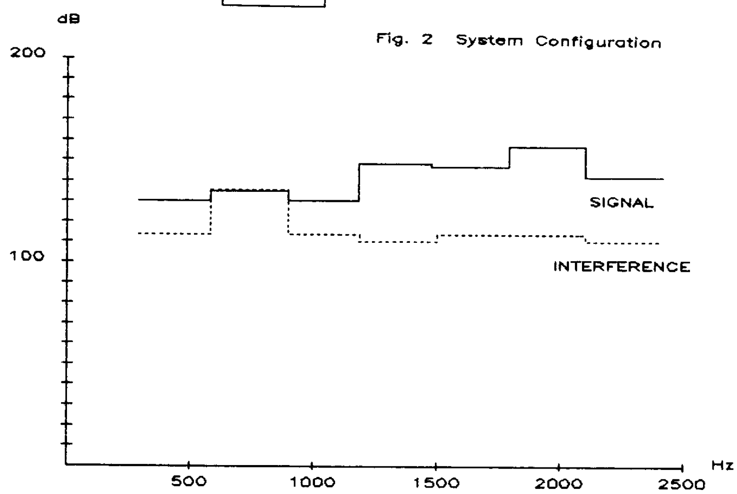

Fig. 3 Signal power and interference power versus frequency in the HF radiochannel