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TRANSMISSION COMBINEE D'UN SIGNAL AUDIO ET DE DONNEES SUR LA MEME LIAISON DE COMMUNICATION VHF

COMBINED TRANSMISSION OF AUDIO SIGNAL AND DATA ON THE SAME VHF COMMUNICATION LINK

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RESUME

Il est présenté un système de communication qui est en mesure de transmettre simultanément un signal audio et des données sur la meme liaison radio, en particulier pour assurer une liaison de données entre un avion et une station au sol, à travers la liaison de communication analogique commune VHF.

Deux différentes techniques de modulation sont considérées: la modulation d'amplitude pour la voix et la PSK pour le données; la modulation d'amplitude pour la voix et la MSK pour les données.

Les résultats obtenus en simulant le nouveau système de communication, avec la modulation PSK et MSK pour les données, sont rapportés. Il est montré comment la solution AM-MSK peut donner de meilleurs résultats par rapport à l'AM-PSK, surtout en raison de la plus grande compacité spectrale de la modulation MSK. En particulier, pour le système AM-MSK, des rapports signal--bruit supérieurs à 20 dB sont rapportés pour les performances du canal de la voix, avec des vitesses de transmission des données de 300 et 600 b/s (valeur qui est considérée, en général, comme satisfaisante pour l'application concernée).

Il est souligné l'intéret que revet le système proposé afin d'accroitre l'efficacité des liaisons de communication air-sol actuelles et de permettre ainsi un échange de données très utile, avec des couts de réalisation modestes grace aux faibles modifications qui sont nécessaires pour l'équipement de bord et de la station au sol ainsi que pour l'organisation du controle du trafic aérien.

SUMMARY

A communication system able to transmit simultaneously an audio signal and data on the same radio link is presented, in particular for assuring a data-link between an aicraft and a ground station by using the usual VHF analog communication link.

Two different modulation techniques are considered: amplitude modulation for voice and PSK for data; amplitude modulation for voice and MSK for data.

The results obtained by simulating the new communication system, with PSK and MSK modulation for the data, are reported. It is shown how the solution AM-MSK performs better than AM-PSK, essentially for the higher spectral compactness of the MSK modulation. In particular, for the system AM-MSK, signal-to-noise ratios greater than 20 dB are reported for the performance of the voice channel, with data rates of 300 and 600 b/s (value usually considered satisfactory for the considered application).

The interest of the proposed system is outlined to improve the efficiency of the actual air-ground communication links, permitting a very useful exchange of data, with low cost of implementation, due to the fact that few modifications are required to aboard and ground equipments and to air traffic control organization.

Transmission combinee d'un signal audio et de données sur la meme liaison de communication VHF

Combined transmission of audio signal and data on the same VHF communication link

1. INTRODUCTION

The present organization of air traffic control (ATC) is based almost completely on the voice communications between the pilot and the ground station. The control station keeps the status of the airways updated and regulates the whole system, communicating with all the aircrafts in its control area [1] [2].

Communications with transoceanic or transcontinental flights are generally performed using HF bands; nevertheless such bands aften present poor propagation. In metropolitan areas, VHF and UHF bands are generally utilized. These bands allow a good communication quality, even though they can only be utilized over limited distances. Moreover, the channels available in these bands are often saturated due to the high density of air traffic, as in terminal areas, especially at some peak hours. This fact often determines delays in departure and arrival of flights and also consequences on the safety of flights.

A solution to this problem, which will probably be adopted in the near future, is the introduction of a digital channel for the automatic transmission of a part of the data and information that are currently transmitted by voice to and from the aircraft. In this way it is possible to reduce the load and the duration of conversations between ground station and aircraft. At the same time, an automatic process of the control operations which today are performed exclusively by the pilot is conceivable.

Small or medium-size aicrafts represent an important part of the whole air traffic in many countries, as for example in Italy. Therefore it is convenient to create a data link which can be extended to these aircrafts as well. This makes it necessary to find solutions having a simple and economical implementation and, if possible, without great modifications to the present apparatus for voice transmission. Almost all the solutions proposed in the literature fall to meet these conditions.

In this paper a possible setup of a data link between station and aircraft, which satisfies the above requirements, is presented. In such a system the data signal modulates the phase of the carrier utilized for voice transmission. Therefore the data link can be created by adding a phase modulator to the present apparatus for voice transmission. Of course, this communication system does not perform as well as other solutions using two separate channels, the first one for voice and the second one for data transmission. Nevertheless, in this paper, it is shown that the proposed communication system achieves an overall performance which can be considered satisfactory for the particular application considered here, where very high data rates are not required. The mutual interferences between the two modulations, amplitude and phase, are investigated using a computer simulation.

2. A DATA LINK USING A HYBRID AMPLITUDE-PHASE MODULATION

The possible solutions for creating a data link between a ground station and an aircraft can be subdivided into two categories [3] [4]:
- specialized data link for air traffic control, integrated into secondary radar;
- VHF data link of universal type, compatible with the voice transmission and not specialized for air traffic control fucntions only.

The first solution, adopted for example in the DABS system, permits a data link of high capacity to be achieved [1] , but presents some important drawbacks. Indeed this solution is very expensive and not easily extendible to small or medium-size airports for many years. At the same time, the possibility of a direct link between aicrafts, without passing through the ground station, is excluded. In this solution, all the aircrafts not equipped with an SSR transponder are excluded from the data link facility.

In many countries, such as Italy, small and medium-size aircrafts represent an important part of the air traffic and therefore it is convenient to develop solutions which can be extended to all air traffic.

In the second category, on the other hand, economical, universal-type systems can be fornd. The solutions in this category can in turn be divided into two subcategories:
1) systems with separate channel, in which data are transmitted on a frequency different from that used for voice transmission;
2) systems with a common channel, in which data and voice utilize the same channel.

A separate channel solution requires availability of a certain number of channels to be destined solely for numerical transmissions and would hence bring about a further increase in the saturation of the bands presently available. Furthermore it would require doubling the communication apparatus aboard the aircraft and hence a cost that may be not neglegible for small aircraft.

In the other subcategory of solutions, on the other hand, the numerical information must coexist in some way with the voice signal. This limits the performance to be expected from such solutions, in contrast to the solutions in the first subcategory, which do not present this type of problem.

The coexistence of voice and data in a single channel may be achieved in various type solutions: for example by means of multiplex with frequency division or time division, or by orthogonal modulations.

The data link here proposed lies in the second category and therefore utilizes the same channel for voice and data transmissions. In this solution voice signals and data modulate the same carrier: the voice modulates the amplitude of the carrier, while data modulate the phase or the frequency of the same carrier. The general block diagram of this system is shown in Fig.1.

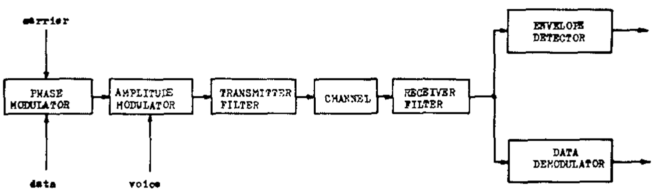

Fig. 1 - Block diagram of the proposed system.

The carrier $A\cos(\omega_0 t+\theta)$, generated by a local oscillator, is first modulated in phase by the data sequence and therefore is of the form

$$s_1(t) = A\cos[\omega_0 t+\phi(t)+\theta] \quad (1)$$

where

$$\phi(t) = \sum_{k=-\infty}^{\infty} d_k g(t-kT) \quad (2)$$

d_k being the k-th information symbol and g(t) being the phase pulse depending on the particular modulation considered.

The signal is then sent to an amplitude modulator, which modulates the amplitude of the carrier by the voice signal f(t). At the output of the AM modulator is

$$s(t) = A[1+mf(t)] \cos[\omega_0 t+\phi(t)+\theta] \quad (3)$$

where m is the amplitude modulation index.

A signal modulated in phase by means of a PSK modulation has a constant envelope. Nevertheless, because of the abrupt discontinuities present in a PSK signal, and hence the considerable extent of its spectrum, when that signal passes through a finite-band system, the envelope of the modulated wave is no longer constant [6].

These envelope variations are particularly damaging in the communication system proposed, because they introduce a distortion which interferes with the voice signal. Such a distortion of course depends on both transmission rate and the modulation method utilized.

Different modulations were analyzed: PSK, FSK and MSK for data transmission.

3. SIMULATION OF THE DATA LINK AND RESULTS

The performance of the communication system described in the previous section was simulated by means of a computer program. The flow-chart of the simulation program is shown in Fig. 2.

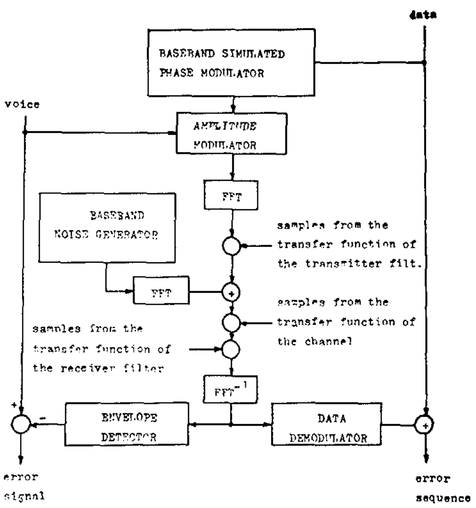

Fig. 2 - Flow-chart of the simulation program.

The bandpass filters in the communication chain were modeled as Butterworth filters with the following characteristics:
- transmitter filter: fourth order, with -3dB single-side bandwidth 7.5KHz;
- receiver filter: eighth order, with -3dB single-side bandwidth 5KHz.

Filtering was performed in frequency domain, while non linear operations, as modulation and demodulation, were simulated in time domain. The transformations from one domain to the other were done using the Fast Fourier Transform (FFT) algorithm.

The signal was processed in blocks of 2048 samples; the sampling frequency was chosen as 19200Hz. In order to estimate the distortion introduced by data signal and phase modulation, the signal output from the AM detector, $f_1(t)$, is compared with the original signal f(t), which modulates the carrier amplitude. An error signal $e(t)=f_1(t)-f(t)$ is therefore obtained.

The simulation program gives some parameters relative to the above error signal. First, the mean noise power N_0 of this error signal is computed and expressed in dBm, taking as reference a disturbance of 1mW. Denoting with S the power of the signal f(t), the signal-to-noise ratio S/N_0 is also computed. Another interesting parameter is the maximum value e_p of the error signal, i.e. the peak error, which indicates the maximum error which can be encountered in this transmission system. All these parameters are obtained by supposing the communication channel as a noiseless channel; in this way the error signal is due only to the interferences of the data with the amplitude modulation.

To characterize the influence of the amplitude modulation on the data, the bit error probability P_e at the data demodulator is computed. In this case the communication channel is assumed to introduce an additive, Gaussian noise, with a noise power density N. In particular four different signals, modulating in the voice channel, were utilized in the simulation, as
- a tone at 937.5Hz frequency;
- a tone at 1875Hz frequency;
- a sum of five tones.

From the obtained results, the following main indications were emerging:
- PSK systems often present poor performance (the signal-to-noise ratio can be lower than 15dB);
- FSK and MSK modulations present higher efficiency (for example AM-MSK systems give S/N greater than 30dB and peak errors lower than 1% in almost cases).

The above differences are essentially determined by the spectral spread of PSK.

In overall FSK and MSK modulations resulted to offer sufficiently good efficiency for practical applications of the propsed system.

REFERENCES

[1] W. L. Ashby, "Future Demand for Air Traffic Services", Proc. IEEE, vol. 50, n. 3, March 1970.
[2] P. R. Drouilhet, "DABS: a System Description", Lincoln Laboratory, ATC 42, FAA-RD-74-189, November 1974.
[3] M. Pent, M. Ajmone Marsan, "Analisi sistemistica preliminare e individuazione di possibili tipi di compatibilitã voce-dati sul canale terra-bordo-terra in VHF", Finalized Project, Ugo Bordoni Foundation; Report II/B/1.2, 1979.
[4] G. Benelli, G. Borghi, V. Cappellini, E. Del Re, S. Gueli, "Combined Amplitude-Phase Modulation for a VHF Communication Link", IEEE Int. Conf. on Communications, Denver, 1981.
[5] G. Benelli, "VHF Radio Link for Ground-Air-Ground Communications Using an Integrated Voice-Data Modulation", Electronics Letters, vol. 18, n. 13, 1982.
[6] L. J. Greenstein, P. T. Fitzgerald, "Envelope Fluctuations Statistics of Filtered PSK and Other Digital Modulations", IEEE Trans. COM-27, n. 4, 1976.