A HYBRID MODULATION FOR THE DISSEMINATION OF WEATHER DATA TO AIRCRAFT

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SUMMARY

Ohio University is continuing to conduct research to improve its system for weather data dissemination to aircraft. The current experimental system transmits compressed weather radar reflectivity patterns from a ground based station to aircraft. Although an effective system, the limited frequency spectrum does not provide a channel for transmission. This introduces the idea of a hybrid modulation. The hybrid technique encodes weather data using phase modulation (PM) onto an existing aeronautical channel which employs amplitude modulation (AM) for voice signal transmission. Ideally, the two modulations are independent of one another. The planned implementation and basis of the system are the subjects of this paper.

BACKGROUND

A system for weather data dissemination to aircraft was developed at Ohio University to improve weather uplink service to general aviation aircraft. This system obtained weather radar reflectivity patterns from the National Weather Service via telephone lines. Weather radar reflectivity patterns are utilized since the transmission of such images has been identified as a method of improving aircraft safety. The image is digitized, compressed using compact codes and run length encoding, modulated using Quadrature Phase Shift Keying (QPSK), and transmitted over a Very High Frequency (VHF) aeronautical channel. In the aircraft, data is demodulated and processed so that the image can be displayed (ref. 1). This system was implemented successfully using a data rate of 2400 bits/second which provides a mean image time of ten seconds per image.

This system offers a potential improvement over the inadequate weather uplink service now in use. The remaining obstacle concerns its placement in the already overcrowded frequency spectrum. A possible solution may be obtained through the use of a hybrid modulation, utilizing both amplitude and phase modulation on the same channel. Currently, voice communication between ground and aircraft is accomplished using amplitude modulation of a VHF carrier. Ideally, this carrier can be phase modulated with the weather data with no interference between the two modulations.

HYBRID MODULATION

A signal using both amplitude and phase modulations can be expressed by:

$$A_c \cdot [1 + k_v\, m(t)] \cdot \cos[2\pi f_c t + \theta(t)]$$

Where m(t) is the amplitude modulated voice signal and $\theta(t)$ is the phase modulated data. Ideally, these two modulations are independent of one another, but due to the band and amplitude limiting necessary for transmission, an interference mechanism is introduced (ref. 2). Generally, a phase modulated signal retains a constant amplitude. However, when this signal is filtered so that its higher frequency energy is removed, envelope variations result which directly interfere with the AM voice in a hybrid modulation. It is important to select a phase modulation which is spectrally efficient, thereby containing less high frequency energy. One such phase modulation method is Minimum Shift Keying (MSK). Research regarding an AM voice/MSK data hybrid signal has shown that the system is feasible under the following constraints: (1) data modulated at a maximum of 2400 bits/second; (2) AM modulated by voice with an index of modulation limited to 0.7; and (3) standard VHF AM communications equipment for both transmitter and receiver (refs. 1-2). It is important to note that the hybrid modulation can utilize the same data rate as the current experimental system.

CURRENT RESEARCH

Although the hybrid AM/MSK system has been studied in theory, it has yet to be implemented. This implementation is the basis of the current research. A Digital Signal Processing (DSP) chip, the TMS320C30 by Texas Instruments, will be used to generate the quadrature and in-phase components of the MSK signal based on digitized weather radar data. The components will be mixed with a carrier generated by a standard VHF AM transmitter for transmission of the hybrid signal. Aboard the aircraft a second DSP chip will be placed in parallel with the AM voice receiver so that data can be demodulated and processed for image display. The proposed implementation of this experimental system is shown in figure 1.

A computer simulation was developed in order to verify to degradation of the AM voice signal due to the envelope variations of the filtered PM signal. The simulation uses an actual voice signal so that the degradation can be judged subjectively. This allows for the testing of the maximum data rates based on voice degradation. The simulation is done by sampling an analog voice signal and using random data bits to generate AM/PM modulated signals. These signals are then passed through two filters, one representing a transmission filter and a second representing the receiver filter. Each sample is then amplitude demodulated to recover the distorted voice samples which are then transformed back into an analog signal for subjective judgment.

Possible alternatives to MSK are being researched also. There exists an entire class of continuous phase modulations which are spectrally more efficient than MSK. Among these are Gaussian MSK (GMSK), Tamed Frequency Modulation (TFM), and Generalized TFM (GTFM) (refs. 3-5). These modulation methods employ a pre-modulation filter to reduce high frequency spectral energy. With a more compact power spectral density, the filtering required for transmission should produce less envelope variation than if MSK modulation is used. The voice degradation simulation should be useful in verifying these assumptions. If these modulation methods prove to be superior to MSK, the overall transmitter design need only be changed by reprogramming the DSP chip, a fairly simple procedure. Much research has yet to be done on these alternative phase modulations, especially regarding determination of the bit error rate associated with each in a hybrid modulation.

CONCLUSION

This paper has described a spectrally efficient technique of combining both an amplitude and phase modulation on the same carrier for the dissemination of weather data to aircraft. The technique, which has been shown to be feasible theoretically, is currently being implemented in an experimental system. This system will allow weather data reflectivity patterns along with voice information to be transmitted using the same frequency spectrum now reserved solely for voice communications. It should also be noted that existing AM receivers can still be used with no modification to demodulate the voice signal. The system also can be used to transmit any other relevant information which might be useful in a data-link.

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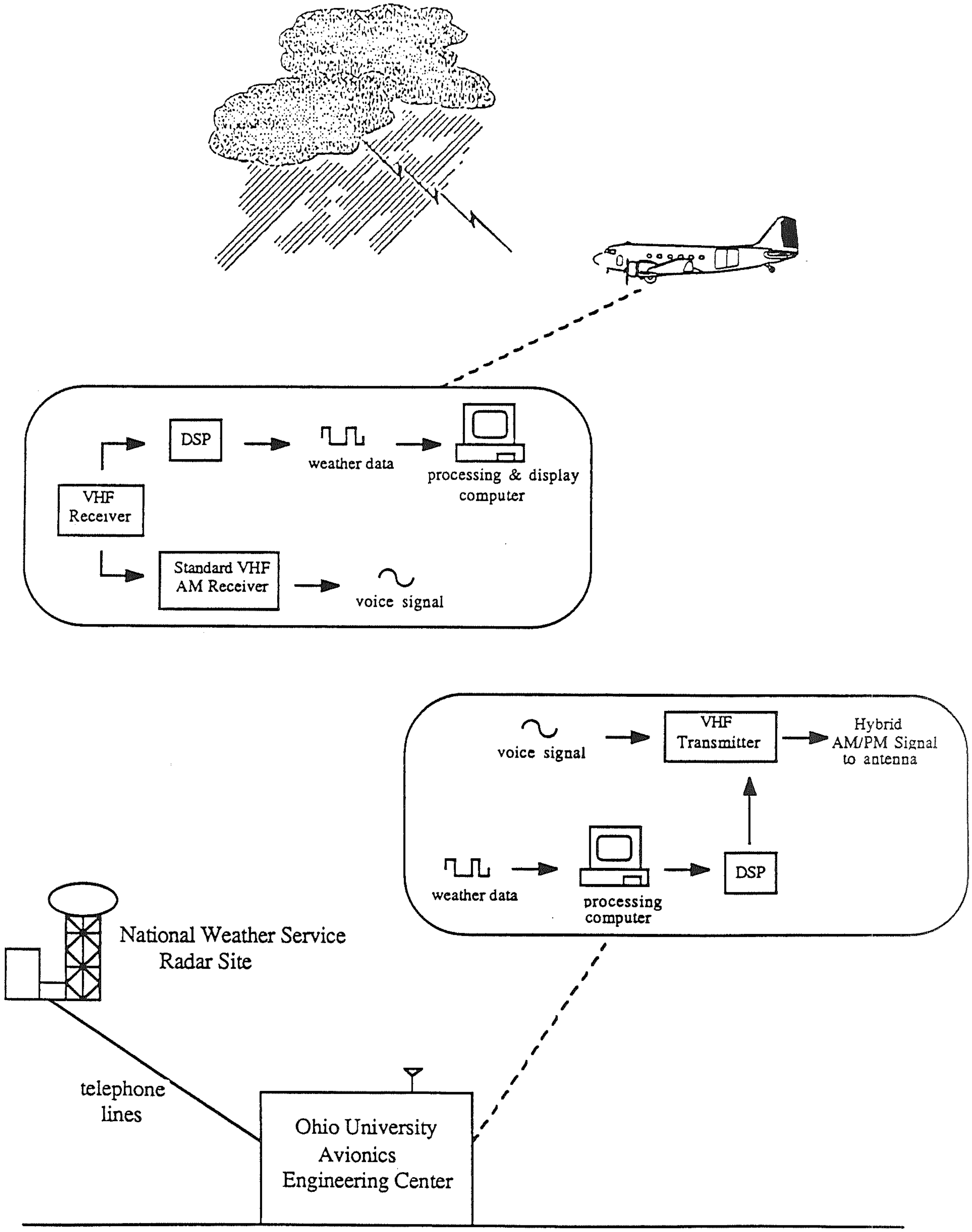

Figure 1. Proposed Weather Data Dissemination System