APPENDIX F*

POSSIBLE TECHNOLOGIES TO BE APPLIED IN A FUTURE VHF AIR-GROUND COMMUNICATION SYSTEM

1. A full digital system with voice and data on the same RF channel

A system design that provides RF channel multiplexing and multiple accessing techniques capable of providing functionally simultaneous access to voice and data link communications on the same RF channel could be useful in fostering the participation of minimum capability users (GA) and users with small airframes. (A single avionics unit and a single RF channel transmit and receive capability is consistent with the present system minimum VHF communications capability.)

2. Technological options considered

2.1 Analogue techniques

Analogue techniques are considered to support voice communications only. It is assumed that data communications will apply digital techniques.

2.1.1 Reduced channel spacing − Double sideband amplitude modulation

The utilization of the VHF band 118 to 137 MHz can be increased by the evolutionary approach of splitting the present 25 kHz channel spacing. This option has been retained for further consideration.

2.1.2 Reduced channel spacing − single sideband (SSB)

Of the SSB options considered amplitude modulation equivalent (AME) appeared to be most practical. This option has been retained for further consideration.

2.1.3 Reduced channel spacing − narrow band frequency modulation

This option was rejected because its use of the spectrum is less efficient than AME.

2.2 Digital techniques

Digital system techniques can provide the fundamental requirements for ATS in any new system, including :

* Appendix F is produced in English only.

a) significant spectrum utilization improvements through efficient low bit rate voice coder (at 4.8 kbits/s); and

b) data link capabilities.

In addition, digital techniques support additional benefits including automated channel management offering a reduction in workload, and potential safety improvements such as reduction of channel selection errors. However, these features need further study.

2.2.1 Voice coding technology

Low bit rate voice coding technology has recently been implemented in various satellite and land mobile systems. Based on developments and operational experiences gained in these industries and continual advancements in this area, it is believed that a voice coder which is available **?**off the shelf" and operates at 4.8 kbits/s will meet the ATS and AOC requirements for the future VHF air/ground radio system.

2.2.2 Time division multiple access

Time division multiple access (TDMA) allocates the spectrum into time slots that can be used for voice and/or data channels. This technique has been retained for further consideration.

2.2.3 Carrier sense multiple access

This multiple access mode is characterized by having the receiver listen to an RF channel to ensure the channel is clear before transmitting. Collisions between competing messages are possible and have to be resolved by retransmissions. This technique has been retained for further consideration.

2.2.4 Distributed reservation multiple access

Distributed reservation multiple access (DRMA) is an algorithm in which messages contend (in a manner similar to CSMA) to set up reservations to transmit voice or data packets in subsequent time slots. It is distributed in the sense that all ground and airborne radios must receive and maintain reservations that are signalled from all users, many in different talk groups. DRMA would perhaps allow up to four voice or data slots per frame in one 25 kHz RF channel. This technique has been retained for further consideration.

2.2.5 Direct sequence spread spectrum techniques

Direct sequence spread spectrum employs a pseudo noise sequence modulation to code each bit of information. This produces an approximately constant power spectral density over the spreading bandwidth. Within the spreading bandwidth, multiplexing of user channels is accomplished by applying unique pseudo noise spreading codes associated with each user channel. The complexity, inflexibility and power control constraints of direct sequence spread spectrum techniques were considered significant problems. Power control constraints were seen as a particular problem, and significant limitations would need to be placed on the number of spread spectrum users that could be supported, and place constraints on the AM users during any transition. This technique will therefore not be given further consideration.

2.2.6 Frequency hopping techniques

Frequency hopping is a form of spread spectrum technique whereby information is passed in different discrete RF channels in a preprogrammed hopping pattern. Within a given RF hopping bandwidth, multiplexing to create different user channels is accomplished by applying unique hopping pattern sequences associated with each user channel. Frequency hopping techniques, while quite complex, were seen to have some potential. However, short-term and time-averaged interference to the AM signal were identified as aspects that would result in performance limits on any frequency hopping system. This technique will therefore not be given further consideration.

2.3 General techniques

The following techniques are considered applicable to both analogue and digital systems.

2.3.1 Dual-frequency channel structure

If two RF frequencies are used for one channel (a different frequency for up and down directions), the lack of the air-air interference path in the frequency planning aspects was expected to give significant increases in the efficient utilization of the VHF band. Such a system would be a dual frequency (DF) system as opposed to a single frequency (SF) system in which up and downlink frequencies are identical.

The potential effectiveness of the DF channel structure has been investigated for the current Federal Aviation Administration (FAA) VHF assignment data base using computer-based frequency assignment tools. The results indicate that a DF channel structure would be about 6 per cent less spectrally efficient than the existing SF structure, at least for meeting near-term system requirements, if a 14 dB protection ratio remains the FAA standard and if the existing non-uniform arrangement of DOCs is preserved. In other words, a system based on the DF structure would need about 6 per cent more frequency resources to support the same number of circuits as a SF system, assuming that all other design parameters of the two systems were identical and that equally effective techniques were used in preparing frequency plans for the two systems. Therefore this technique is not considered further.

2.3.2 Coded squelch

A coded squelch reduces the nuisance factor of pilots receiving interfering signals when no desired signal is present. The land mobile industry coded squelches (continuous tone-coded squelch system (CTCSS) and continuous digital-coded squelch system (CDCSS) use sub-audio modulation in analog radio systems. The narrow bandwidth available to this technique requires a considerable length of time to transmit enough data to open or close the squelch. This time is specified as 150 to 373 milliseconds for the receiver and 150 to 350 milliseconds for the transmitter. This time is probably too long to be of significant use for ATS applications. A wider bandwidth would be needed to decrease the time required for reliable squelch operation.

Any digital system naturally offers a "coded squelch effect" against adjacent channel interference and other in-band noise-type signals in the absence of a desired signal since these are uncorrelated with desired signals and are thus readily discriminated by a receiver. The ability to discriminate against co-channel interference is more of a challenge in the VHF air-ground environment even for digital systems since the interference is highly correlated with the desired signal. The timing aspects of a TDMA approach can additionally provide discrimination against co-channel interference as a result of the very low probability of the interfering signal correlating in time with the narrow time-of-arrival window defined by the desired ground station.

2.3.3 Trunking techniques

The concept of trunking seeks to enhance capacity through dynamic allocation of pooled communication resources on a demand basis. The complexity to achieve an efficiency increase would be unattractive in areas with low traffic levels, and in high density areas the high traffic levels would not allow significant channel savings unless a low grade-of-service was considered acceptable. This technique will therefore not be given further consideration.

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