

A DIGITAL TDMA SYSTEM FOR VHF AERONAUTICAL COMMUNICATIONS ON 8.33 KHZ CHANNELS

Fred Studenberg, Rockwell Collins, Inc, Melbourne, FL

Abstract

VDL Mode E is a digital TDMA VHF communications system providing voice and data services for civil aeronautical communications. It is proposed as an upgrade for the existing 8.33 kHz channel analog AM system currently used in Europe.

8.33 kHz channel compatibility of VDL Mode E permits a simple transition from the existing analog system by “dropping in” digital VDL Mode E channels on current 8.33 kHz analog AM assignments.

The voice and data capacity of VDL Mode E will provide adequate capacity for forecasted air traffic operations in Europe to at least the year 2050.

Introduction

To provide for an interim solution to congestion on 25 kHz channel Civil Aeronautical VHF communications in Europe, conversion to 8.33 kHz channels began in 1999. The 8.33 kHz solution was intended to be used until a more modern digital system offering desirable safety improvements, integrated voice/data capabilities, and more channel capacity could be developed, validated, and deployed.

One candidate system for use in Europe to replace 8.33 kHz AM is VDL Mode 3. VDL Mode 3 is being developed by the FAA and industry partners for the Next Generation Air-Ground Communications system (NEXCOM) for VHF Air Traffic Control communications in the United States. This digital TDMA system operates in the 118-137 MHz aeronautical band on existing 25 kHz channels and provides up to 4 independent digital voice or data circuits.

To provide VDL Mode 3 capabilities, Rockwell Collins is developing the VHF-2100 (Figure 1) and VHF-4100 VHF Communications Transceivers.

These products are multi-mode VHF Comm Transceivers (VDL Modes A/2/3, and 8.33/25 kHz voice AM capabilities) for the Air Transport and Business Jet markets. The VHF-2100 Air Transport product will be certified and available for sale in Qtr 1 of 2005 with the Business Jet version available in Qtr 3 of 2006.



Figure 1. VHF-2100

VDL Mode 3 will provide a X4 (300% increase) in voice channel capacity over the present 25 kHz AM system and the ability to use simultaneous voice and data operations on a single RF channel. It also provides desirable safety and security improvements as well as reducing pilot workload by providing automatic frequency selection. The 25 kHz channel compatible spectrum of VDL Mode 3 permits a straightforward path for transition from the existing 25 kHz analog AM system.

For use in the 25 kHz environment of the United States, VDL Mode 3 is a practical solution for the requirement of expanded channel capacity and integrated voice/data capability. However, implementation of VDL Mode 3 in the evolving 8.33 kHz environment of Europe will be challenging due to frequency management issues associated with the spectrum incompatibilities. Figure 2 illustrates the mechanism that makes this task difficult as well as inefficient in spectrum capacity improvement.

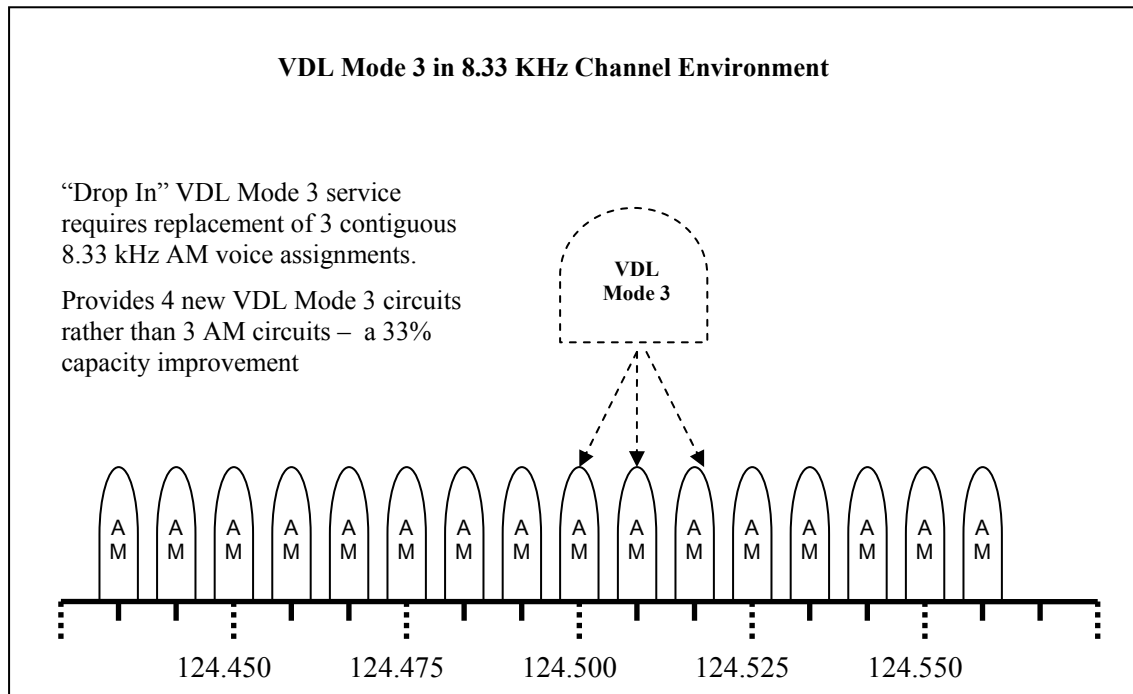


Figure 2. VDL Mode 3 Implementation in 8.33 kHz Environment

Proposed System

To address these issues, Rockwell Collins has conducted preliminary design efforts on a modification of the VDL Mode 3 design to permit it to operate on 8.33 kHz channels. We believe this 8.33 kHz based system, currently known as VDL Mode E, will meet all of the unique European requirements for a next generation digital integrated voice/data communications system by providing a solution for all known safety and security issues as well as a significant capacity improvement.

The VDL Mode E system will be compatible with the recommendations and future traffic loads defined in the Eurocontrol paper, “Operating Concept of the Mobile Aviation Communications Infrastructure Supporting ATM beyond 2015”, dated 30 April 2002.

If implemented in the near term in the European system (now less than 10% transitioned from 25 kHz to 8.33 kHz) VDL Mode E provides a X5 circuit capacity improvement for voice operation. If implementation is delayed until the current system is completely converted to analog

8.33 kHz, it will still provide a X2 circuit capacity improvement.

With integrated voice/data or data only capability, VDL Mode E provides more channel efficiency and also offers a clear migration path from the VDL Mode 2 CSMA system used in the new CPDLC Link 2000+ program (Controller-Pilot Data Link). For ATC use, a TDMA system, such as VDL Mode E, is preferred since it will provide much higher system integrity and availability than a CSMA system such as VDL Mode 2. It also eliminates many VHF Comm co-site interference issues by permitting simultaneous data and voice operations with a single VHF transceiver.

8.33 kHz compatibility of VDL Mode E permits a simpler transition from the existing analog system by “dropping in” digital VDL Mode E channels on current 8.33 kHz analog AM assignments. No special sub-bands are needed as with other proposed digital systems operating in the VHF range. Figure 3 illustrates the simple VDL Mode E upgrade plan as well as the significant spectrum capacity improvement available.

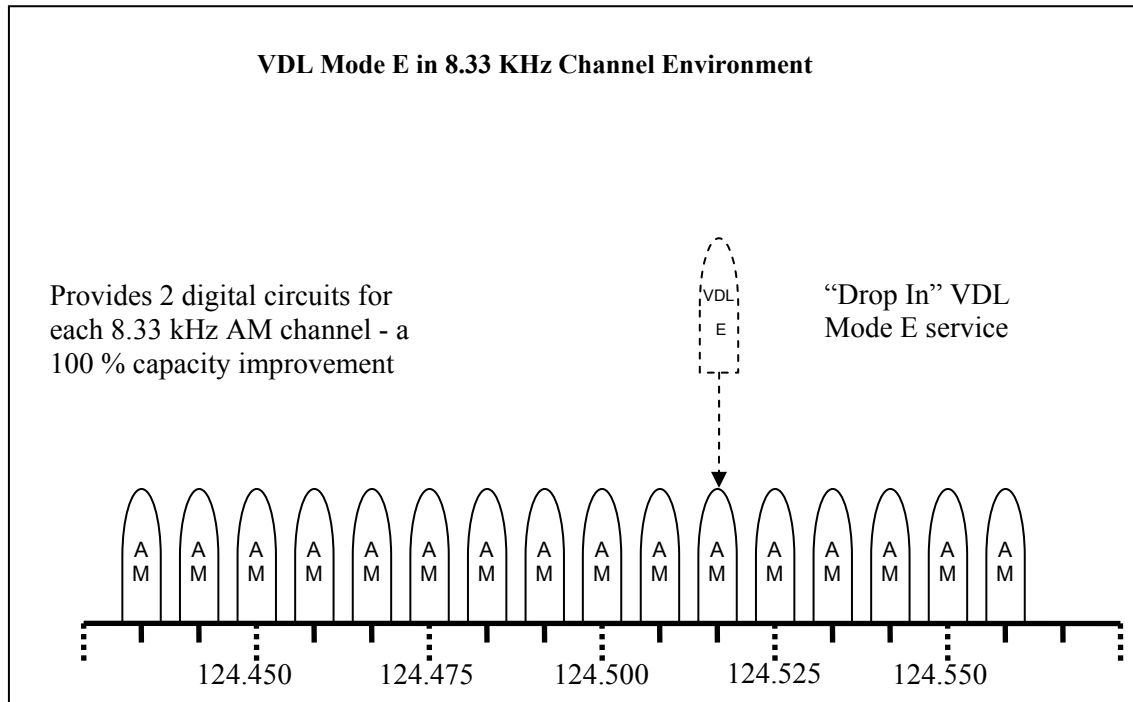


Figure 3. VDL Mode E Implementation

By planning for VDL Mode E as the replacement digital system in Europe, frequency planners can freely implement interim 8.33 kHz analog AM voice systems to relieve channel shortages with assurance that there will be minimal frequency management issues associated with introduction of a new compatible digital system.

VDL Mode E System Description

VDL Mode E is based on the validated VDL Mode 3 system, with re-use of the 4.8 kb/sec VOCODER algorithm, all network protocols, and proven D8PSK RF waveform. The risks associated with developing, validating, and deploying VDL Mode E are greatly reduced compared to a completely new system using untested RF waveforms and protocols.

VDL Mode E achieves the 8.33 kHz spectrum compatibility by a reduction of the symbol rate and “alpha” factor of the VDL Mode 3 D8PSK waveform.

Tests of Prototype Transmitter

For a reference, Figure 4 shows the measured spectrum and mask of a production version 8.33 kHz analog AM transmitter. This measurement was taken with a spectrum analyzer in peak hold mode with 10 seconds of a normal voice transmission.

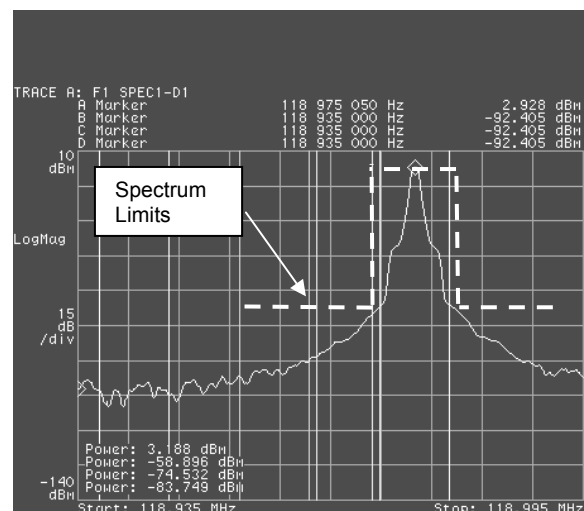


Figure 4. Spectrum of 8.33 kHz AM Transmitter

Figure 5 presents the spectrum of a VDL Mode E waveform along with the same spectrum mask used for 8.33 kHz AM.

This spectrum was provided by a prototype version of the VDL Mode E waveform installed in the Rockwell Collins VHF-2100 multi-mode VHF Communications Transceiver.

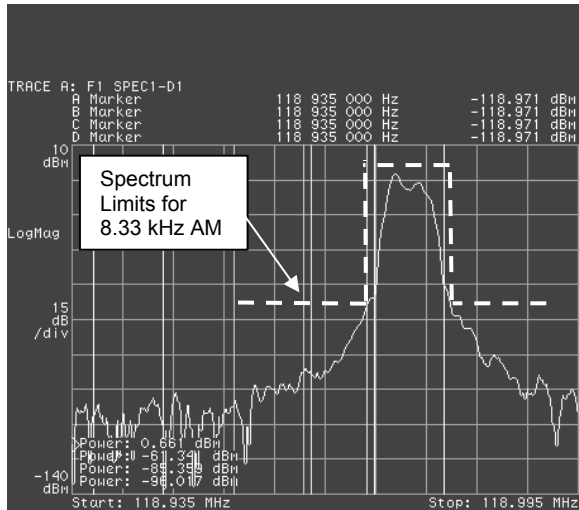


Figure 5. Spectrum of VDL Mode E Transmitter

Figure 6 shows the RF envelope from the prototype VDL Mode E transmitter. This is a 43 msec data burst repeated every 120 msec. It represents the RF waveform of a transmitter operating on either slot of the two slot VDL Mode E TDMA system.

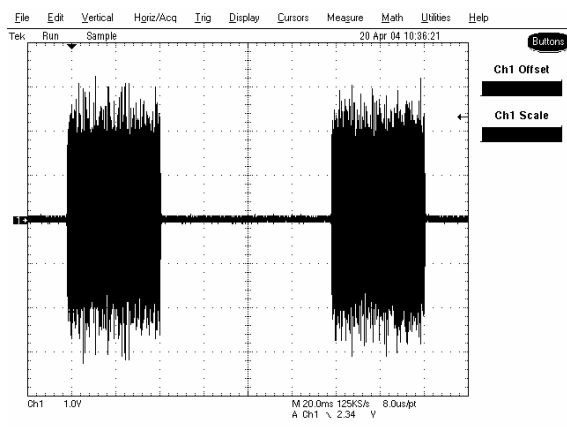


Figure 6. VDL Mode E RF Envelope

Figure 7 shows that the Error Vector Magnitude (EVM) performance of the prototype VDL Mode E transmitter is 1.5%. This is well

within the 6% limit used in the VDL Mode 3 system and also suggested as the specification for VDL Mode E.

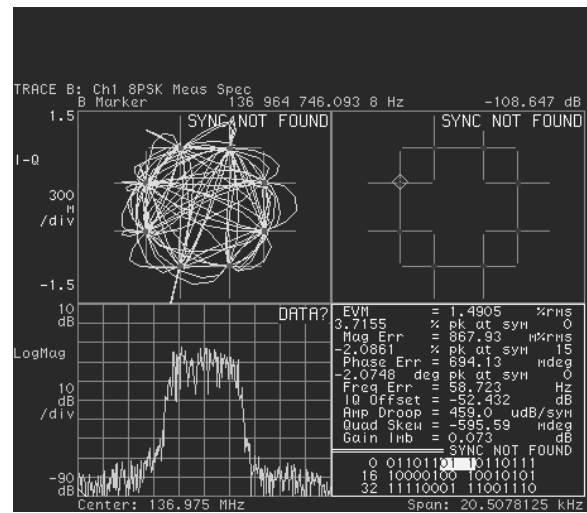


Figure 7. EVM Performance of VDL Mode E

These preliminary tests demonstrate that the VDL Mode E waveform can be hosted by the same hardware platform used for VDL Mode 3 while providing adjacent channel performance equal to or better than the 8.33 kHz analog AM system.

TDMA Channel Structures

Figures 8, 9, and 10 contain comparisons of the TDMA channel structures of the VDL Mode 3 and VDL Mode E systems. A special three slot configuration is required in the VDL Mode 3 system for long range communications to provide the propagation guard time needed to prevent interference between time slots.

The VDL Mode E channel structure is a two slot configuration with 60 msec for each time slot rather than 30 or 40 msec as used in the VDL Mode 3 system. The longer slot time for VDL Mode E and use of two time slots is a result of the reduction in symbol rate to provide the 8.33 kHz spectrum compatibility. With 385 nautical mile propagation guard time between slots, no special configuration is needed for long range operation.

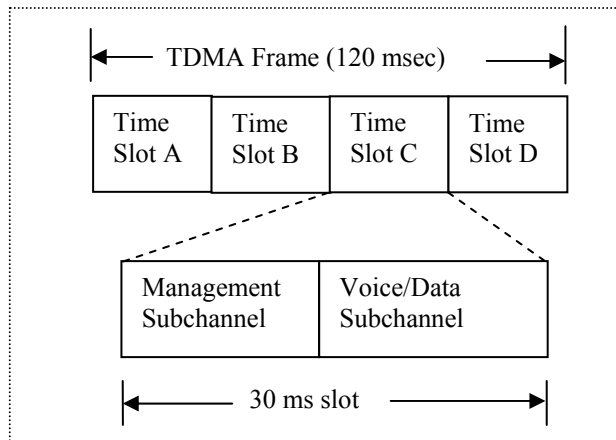


Figure 8. VDL Mode 3 (Normal Range)

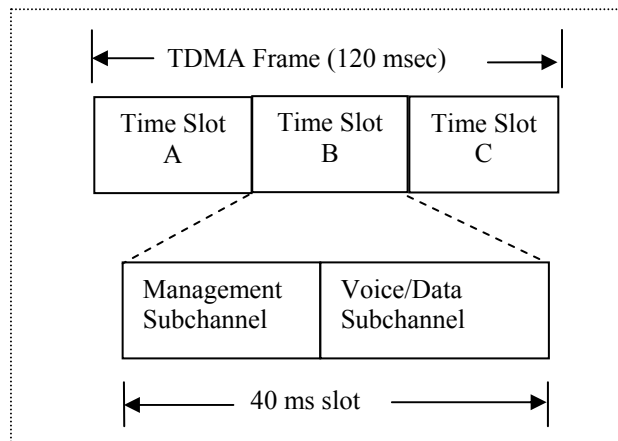


Figure 9. VDL Mode 3 (Long Range)

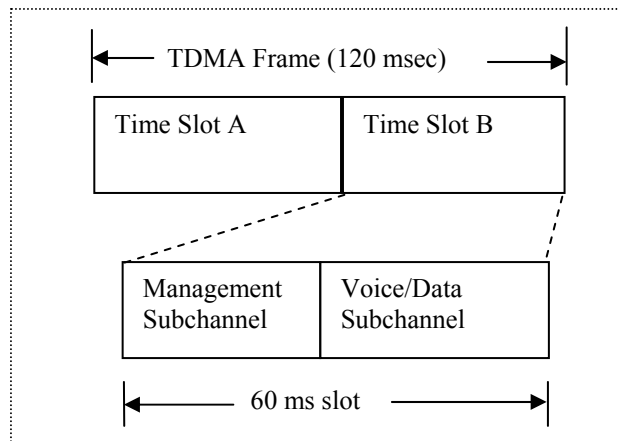


Figure 10. VDL Mode E Channel Structure

VDL Mode E Key Characteristics

Table 1 presents a comparison of the Key Characteristics for VDL Mode E and VDL Mode 3 systems.

Table 1. Comparison of Key Characteristics

Key Characteristic	VDL Mode 3	VDL Mode E
Frequency Range	118-137 MHz	Same
Data rate of voice/data circuits	4.8 kb/sec	Same
Frame Update Rate and MAC	120 msec TDMA frames with Management Channels	Same
Voice	4.8 kb/s DVSI VOCODER	Same
Data	4.8 ks/s and functionally simultaneous with voice	Same
Receiver Sensitivity	-98 dBm	-101 dBm (3 dB improvement due to lower bandwidth)
Transmitter Power	15 watts	7.5 watts (less power needed because of improvement in receiver sensitivity)
Co-Channel Interference Performance (D/U)	20 dB (typical 15 dB for acceptable VOCODER performance)	Same
Channel Spacing	25 kHz	8.33 kHz
Bit rate	31.5 kb/sec	15.75 kb/sec
RF Waveform	D8PSK, raised cosine, alpha = 0.6	Same except alpha = 0.3
Number of Slots (circuits) per RF Channel	3 or 4 (3 slot system needed for sectors with ranges beyond 210 nmi)	2 (385 nmi propagation guard satisfies range requirements for all conditions)

VDL Mode E Channel Identification

Operator selection of VDL Mode E channels can be accommodated using the same 6 digit display radio tuning panels developed for 8.33 kHz AM and VDL Mode 3. Table 2 illustrates one method for identifying the channels and time slots for VDL Mode 3

Table 2. A Method of Identifying VDL Mode E Channels

Frequency (MHz)	Channel Spacing (kHz)	Channel	Mode
118.000	25	118.000	25 kHz AM
118.000	25-A	118.001	VDLM3 / Slot A
118.000	25-B	118.002	VDLM3 / Slot B
118.000	25-C	118.003	VDLM3 / Slot C
118.000	25-D	118.004	VDLM3 / Slot D
118.000	8.33	118.005	8.33 kHz AM
118.000	8.33-A	518.005	VDL Mode E / Slot A
118.000	8.33-B	618.005	VDL Mode E / Slot B
118.0083	8.33	118.010	8.33 kHz AM
118.0083	8.33-A	518.010	VDL Mode E / Slot A
118.0083	8.33-B	618.010	VDL Mode E / Slot B
118.0167	8.33	118.015	8.33 kHz AM
118.0167	8.33-A	518.015	VDL Mode E / Slot A
118.0167	8.33-B	618.015	VDL Mode E / Slot B
118.025	25	118.025	25 kHz AM

VDL Mode E Configurations

Three configurations are proposed to meet the current and future VHF ATC Communications needs in Europe:

- 2V to provide two independent digital voice circuits
- 2D for a full duplex digital data circuit optimized for CPDLC operations. One slot is dedicated to uplinks and one slot for downlinks. This configuration very efficiently utilizes channel capacity by consolidating data communications from different flight phases and user groups on a given RF channel rather than segregated channels as in existing voice systems.

By providing 60+ independent CPDLC circuits on each 8.33 KHz channel, a system using just 85% of available 8.33 kHz channels in Europe can support 116,000 simultaneous aircraft even without the additional benefits of frequency re-use. This capability can accommodate projected traffic growth in Europe beyond the year 2050¹.

- 2S for diversity digital voice with wide area coverage. The system performance is equivalent to that provided by the existing 25 kHz analog AM offset carrier (CLIMAX) system

VDL Mode E System Features

VDL Mode E retains all the safety and operational features of VDL Mode 3 while adding new capabilities and performance improvements.

Key VDL Mode 3 Features Retained

- TDMA operation using dedicated management sub-channels for “stuck mic” protection, elimination of simultaneous transmissions, urgent downlink, controller

override, next channel uplink, and prevention of unauthorized operation.

- Validated VDL Mode 3 VOCODER algorithm
- High integrity, independent 4.8 kb/s voice or data circuits on each RF channel
- Robust, proven D8PSK waveform

Improvements for European Operation

- 8.33 kHz channel compatibility
- 3 dB increase in RF link margin

Provisioning For VDL Mode E

Based on preliminary tests and investigations, VDL Mode E will be totally compatible with the hardware designs of multi-mode airborne radios now being developed by Rockwell Collins for VDL Mode 3. VDL Mode E will require only a software update of these new products. It is expected that ground station equipment for VDL Mode E can similarly evolve from current VDL Mode 3 ground station designs.

As illustrated in Figure 11, new avionics with both VDL Mode E and VDL Mode 3 capabilities can provide users with a unified global solution to VHF channel congestion issues and the capability for more efficient digital data operation.

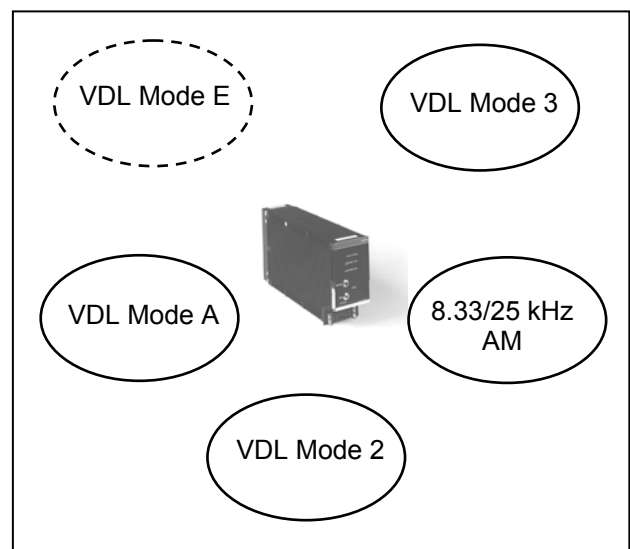


Figure 11. VHF Multi-Mode Communications

¹ Eurocontrol paper, “Operating Concept of the Mobile Aviation Communications Infrastructure Supporting ATM beyond 2015”, dated 30 April 2002.

Future Efforts

This paper has shown that VDL Mode E has significant advantages and benefits for use in the 8.33 kHz VHF environment in Europe.

Rockwell Collins is interested in collaborative efforts with stakeholders to further investigate the capabilities and potentials of this proposed system.