

2114210 Independent Project Proposal Video Broadcasting in an EM environment

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Project Proposal:

***Resilient Video Transmission in
a Degraded Electromagnetic
Environment***

Embedded Electronic Systems, Year 4

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Resilient Video Transmission in a Degraded Electromagnetic Environment

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Resilient Video Transmission in a Degraded Electromagnetic Environment

Introducing the problem

The importance of DVB:

Video Broadcasting is an important part of society. It allows information to rapidly be spread to a wide audience, and provides multiple services, including:

- Entertainment
- Education and awareness to topics that would otherwise remain undiscovered
- Shaping of public opinion and policy
- Real-time connectivity to a large audience

How does DVB work?

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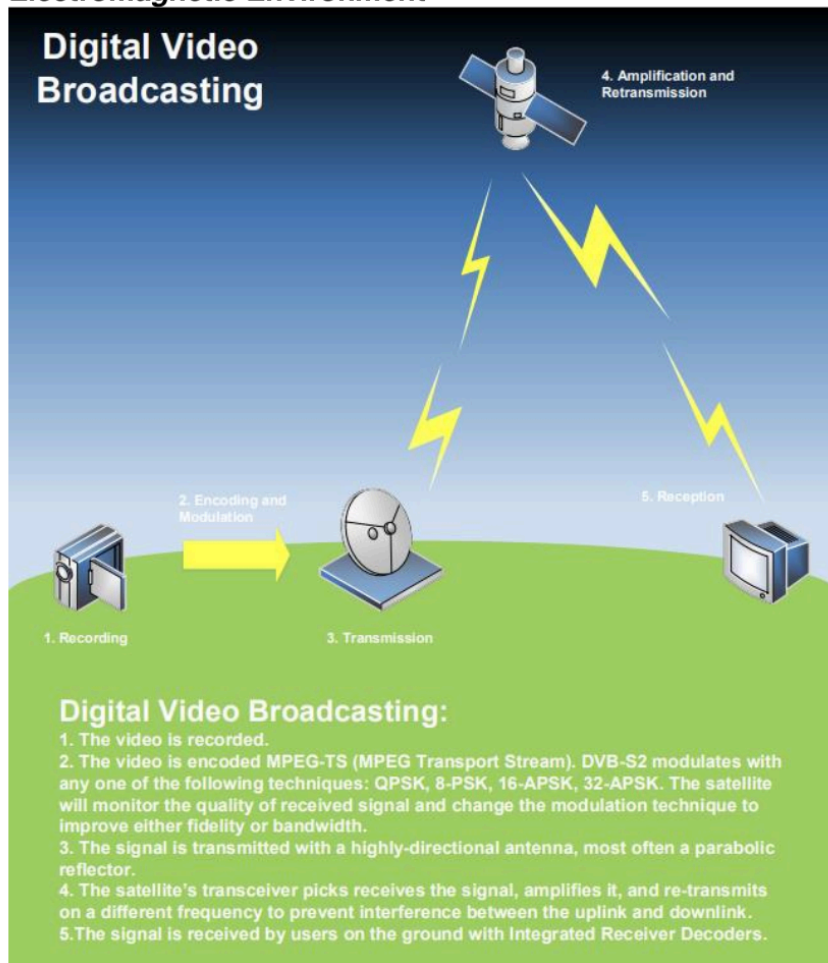


Figure 1. Operation of DVB-S2 protocol [1].

Susceptibility of DVB-S2:

Since most video broadcasting systems rely on satellite communication to function, they are vulnerable in many ways to “degraded electromagnetic environments”:

- **Coronal mass ejection:** large clouds of ionised particles launched by the sun that can severely damage or destroy satellites.

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- **Solar winds:** ionised solar radiation that has the potential to damage satellites. Although the earth's ionisation field is strong enough to protect from all solar winds on the surface of the earth, this is not the case for all satellites in orbit.
- **High altitude nuclear event:** when nuclear weapons are detonated in space, they generate an electromagnetic pulse that can easily destroy nearby satellites, even if they are not within the blast radius.
- **Anti-Satellite (kinetic) weapons:** shooting down satellites used for relaying the DVB broadcast.
- **Jamming:** Actors seeking to disrupt satellite broadcasting can do so with little technical requirements. This makes the medium susceptible to not just state actors, but also activist groups, militias, or terrorist organisations. Jamming is possible on the uplink and downlink.

Proposed Project:

This project seeks to mitigate the risk to video broadcasting in a degraded electromagnetic environment, and will:

- Evaluate the use of alternative technologies for video broadcasting, such as:
 - Use of different transmission protocols
 - Use of different satellite constellations
 - Use of different bands of the spectrum
- Develop a redundant video transmission system. This system will act as a relay to a DVB transmitter in a different geographic location.

This project will improve the integrity of mass communication in a disaster, allowing emergency instructions to be spread to a large audience, and enabling journalism to continue.

Project Aim

The aim of this project is to improve the resiliency of video broadcasting in a degraded electromagnetic environment. This means that it must have a measurable improvement in the level of white (Gaussian) noise resistance compared to standard DVB-S2 broadcasting. Because the disasters listed above vary in strength and functionality, this project will treat any noticeable improvement in noise resistance as a success (with the goal of improving noise resistance to the highest level possible). The deadline for this is 6th May 2025.

Deliverables:

This project will produce:

- A report on possible techniques to improve video transmission performance in a degraded electromagnetic environment.
- A "relay station" that will move the video broadcast outside of the area of disaster such that conventional broadcasting can resume

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- A full design pack for the relay station, including: circuit schematics, PCB design files, block overview diagram, bill of materials, software design document, copies of all code used, and any other relevant design files.

Background Research

Degraded EM environment:

Coronal mass ejection

Coronal mass ejections are large bursts of plasma that erupt from the sun. This plasma generates large magnetic fields and have the possibility of damaging sensitive electronics (such as satellites). Typically, the earth's ionosphere protects from these events, but if they are large enough that is not the case. Satellites are at increased risk due to their position high above the earth (further up in the ionosphere). [2]

Solar winds

Solar winds are constant streams of charged particles that travel through the solar system. They have the potential to cause damage to electronics by causing bit-flips (a software error where a stored value has been changed, potentially changing how software runs). [3]

DVB-S2

DVB-S2 (Digital Video Broadcasting, Version 2) is the primary protocol for digital video broadcasting. It uniquely utilises adaptive coding and modulation (ACM) techniques, meaning the modulation scheme and level of coding is adapted naturally to find the optimal trade-off between data integrity and transmission speed, improving bandwidth by up to 30% when compared to DVB-S1 [4]. This means that DVB-S2 has much better resistance to degraded EM environments than most satellite protocols. However, degraded electromagnetic environments will slow down transmission with the possibility of stopping successful reception entirely.

Different parts of the radio spectrum

Band:	Frequency:		Use:
	Range:	Unit:	
Extremely low frequency	3-30	Hz	Not enough bandwidth for video transmission
Very Low Frequency	30-3000	Hz	Not enough bandwidth for

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			video transmission
Low Frequency	30-300	kHz	Not enough bandwidth for video transmission
Medium Frequency	0.3-3	MHz	Not enough bandwidth for video transmission
High Frequency	3-30	MHz	Not enough bandwidth for video transmission
Very High frequency	30-300	MHz	Possibly enough bandwidth for incredibly low fidelity video transmission, potentially useful for intelligence gathering purposes, not good enough for newscasting.
Ultra-High Frequency	0.3-3	GHz	Contains enough bandwidth for standard video transmission, but maintains transmission strength, Useful in areas of worse atmospheric weather.
Super High frequency	3-30	GHz	Significant bandwidth allows for transmission of multiple high-fidelity streams. DVB-S2 typically works within this band.
Extremely High Frequency	30-300	GHz	Atmospheric absorption and cost are both too



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			high to feasibly operate here
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Table 1. Bands of the Radio spectrum [5].

Free-space losses

The Friis Transmission equation provides a ratio of the transmitted and received power for a transmission system (loss). The loss is calculated with the directivity of both antennae, the wavelength, and the distance between the transmitter and receiver. Given below:

$$\frac{P_r}{P_t} = D_t D_r \left(\frac{\lambda}{4\pi d} \right)^2$$

Equation 1. Friis transmission Equation. [6]

This equation is used to calculate the power lost from the transmitting to receiving antenna. It's important to note that the receiving antenna must be in the far field of the transmitting antenna for this equation to work.

It will be important to consider free-space path losses when designing the relay station, as it determines the effective range. The equation shows that gain is directly proportional to the square of the wavelength. It can therefore be derived that the loss is directly proportional to the square of the frequency.

Research already conducted

Related research already conducted includes:

- **DVB-S2 ACM:** The Adaptive Coding and Modulation of digital video broadcasting, allowing data rate to be changed depending on received signal strength. [7]
- **DVB-NGH:** The "next generation handheld" variation of DVB includes advanced Forward Error Correction (FEC) codes to allow the receiver to correct and transmission errors without further transmission requirements [7]
- **Cognitive Radio:** [8] monitors the spectrum and can select the clearest frequency with the least noise. This can work well against narrow-band jamming where the issue only lies on certain frequencies

Project Design

Development method

The primary development method used for this project will be the scrum. This method breaks work down into short "sprints" of intensive work and rapid progress. Each sprint has a review at the end to provide feedback and ensure project is on

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task. Sprints naturally improve focus as they provide clear, near-term deadlines, and clear near-term definitions of success and failure.

This method was selected for the following reasons:

- The short timeline of the project requires advanced to be made quickly
- Since the solution to the problem is not defined (finding the best solution is part of the project), development needs to be adaptable to whatever direction works best
- Regular sprints provide accountability with project supervisor, ensuring the project stays within the planned schedule and scope
- Working primarily by myself (with direction and support provided by PTA), it is easier to manage the intensive time costs during sprints.

It will be important to schedule working time primarily for the project as “sprints” require the majority of my time when active. Other work and university projects will need to be scheduled into free spaces.

Tools

Development tools

- KiCad PCB designer: PCB designer available at UWTSd and on corporate Dstl systems
- Proteus circuit simulation: license already provided by UWTSd, with appropriate skills and experience already obtained from previous projects
- Matlab's Simulink: will possibly be used to simulate RF transmission and reception with the presence of a AWGN (Additive White Gaussian Noise) channel.

Compatibility tools

- Microsoft teams: available on Dstl corporate systems and university IT. This will be used to regularly chat with project supervisors
- Cisco Jabber: used to contact other Dstl project stakeholders such as my line manager, the project manager, and project technical authority.

Testing tools

- Anechoic chamber: to test experimental RF transmission in a safe, legal environment
- Spectrum Analyser: to test the frequency and power of transmitted signals
- Signal analyser (if resource permits): to analyse any protocols being used (e.g. DVB-S2)
- Multi-meter: for conducting power-draw calculations
- Oscilloscope: for verifying PCB functionality

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Data analysis approach

- **Transmitted and Received power:** will be collected using a spectrum analyser and multi-meter. This will be used to estimate and effective range for the system, this range will be compared to probable sizes of different disasters to determine if it can move the broadcast outside of the disaster zone.
- **Power draw:** Will be analysed with multi-meter to determine the power requirements (and therefore expected lifespan if on batteries, or infrastructure requirements if being powered)
- **Frequency Envelope:** Collected with spectrum analyser to determine if frequencies used are within the allowed power envelope, and their potential interference from neighbouring frequencies.

Resources and Planning

Resources

- Anechoic chamber
- Spectrum analyser (appropriate for chosen frequency)
- Signal analyser (if resource permits, not strictly essential)
- Multi-meter and other basic hand tools
- External PCB production
- Components budget ~£250
- Computer
- CAD software for PCB and circuit design

Work Breakdown Structure

Project work areas and task breakdown:

W1 – Project Planning

T1.1 – Statement of Requirements

T1.2 – Bill of materials

T1.3 – Project Schedule adjustment

T1.4 – Meeting with project supervisor and Project Technical Lead

T1.5 Project reporting:

T1.5.1 Project Proposal writing

T1.5.2 Interim viva preparation

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T1.5.3 Final Viva Presentation

T1.5.4 Final Report Creation

T1.5.5 Poster creation

W2 – Research and Design

T2.1 – Analysis of COTS solutions

T2.2 – Development of own solution

T2.2.1 – Spectrum selection (band and frequency)

T2.2.2 – Chip Selection

T2.2.3 – Circuit Design

T2.2.3 – PCB Design

T.2.2.4 – Antenna Design

W3 – Construction

T3.1 – Component ordering

T3.2 – Delivery Confirmation

T3.3 – Component Inspection

T3.4 – Purchasing/production of antenna

T3.5 – Assembly of Components

W4 – Software development

T4.1 – Protocol testing

T4.2 – Algorithm design

T4.3 – Programming of chip

W5 – Test and Analysis

T5.1 – Develop testing process

T5.2 – Test radio hardware

T5.3 – Testing of software

T5.4 – Combination of hardware and software testing

W6 – Evaluation and Re-design

T6.1 – Performance evaluation of radio

T6.2 – Modification of radio

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Schedule



Figure 2. Project Schedule

Critical path

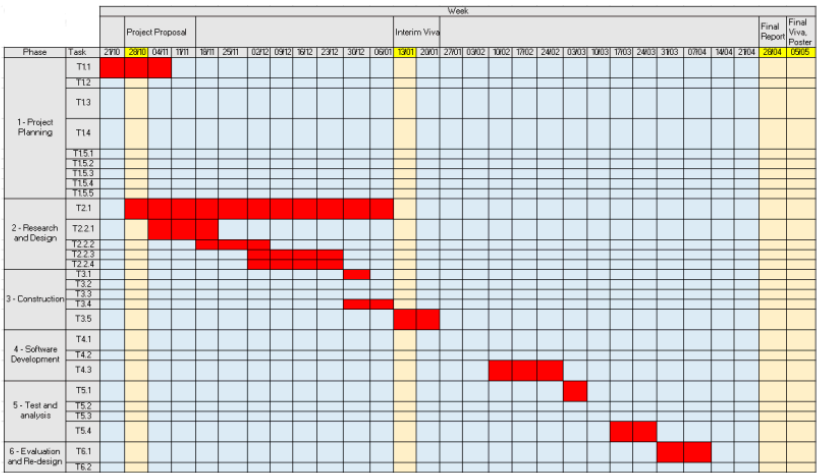


Figure 3. Critical Path

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Tasks in red are considered “critical tasks”, which other tasks require the completion of before they can begin. Please see “work breakdown structure” section for a description of different tasks.

Deliverables

- Report of viability of different techniques to improve performance in a degraded EM environment (e.g. different frequencies, increasing transmission power, increased antenna directionality, using different constellations, using a relay station)
- Physical Video Relay station
- Relay station documentation pack

References

- [1] J Lonsdale. DSTL, "Digital Video Broadcasting" unpublished.
- [2] Attrill, G.D.R, "Low coronal signatures of coronal mass ejections: coronal “waves” and dimmings”, University College London, 2009.
- [3] The HESPERIA HORIZON 2020 Project and Beyond, “Solar Particle Radiation Storms Forecasting and Analysis”, 1st ed. Springer, 2018
- [4] Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications; Part 1: DVB-S2, ETSI EN 302 307-1 V1.4.1, European Telecommunications Standards Institute, Oct. 2014.
- [5] H. Mazar, “Radio Spectrum management: policies, regulations, and techniques”, 1st ed. Wiley, 2016
- [6] J A. Edminster, “Schaum’s outline of theory and problems of electromagnetics”, 2nd ed. McGraw-Hill, 1995.
- [7] Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications; Part 2: DVB-S2 Extensions (DVB-S2X), ETSI EN 302 307-2 V1.1.1, European Telecommunications Standards Institute, Feb. 2015.
- [8] Tonu Trump. (2017). Cognitive radio (T. Trump, Ed.). IntechOpen.

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

74/100

Module Code/ Module Name	ACCA6020 / INDEPENDENT PROJECT	
Student Name	Jack Lonsdale	
Student Number	2114210	
PROJECT PROPOSAL FEEDBACK		
Introduction / A&O: Project title; Identification of a specific problem to be investigated; Well-defined aims and SMART objectives; Explaining why this project is worth doing; Discussion of what the project needs to do in order to be a success; Description any deliverables that will be produced at the end of the project.	Max. Marks	Marks Obtained
Good choice of project title. The problem is well defined. The aims of the project and the rational of the project is clearly stated. The objective provided is good, it would have been better with a SMART objective as few components are missing.	20	15
Background to the Project / Literature Review: Description of how the work to be done by in the project relates to the work identified in the literature review; Discussion of any	20	15

ethical issues raised by the project Identifying what has already been done within the field; Topic familiarity; Brief literature review using appropriate sources – 6-8 journal papers and book chapters rather than just websites; Selection of relevant models & concepts		
The background demonstrates a strong understanding of the problem. Ethical considerations are mentioned. Demonstrates good topic familiarity. Inclusion of more peer reviewed research article would have strengthen the document.		
Project Design: Clear statement of which development methods are to be used and why they are appropriate; Clear statement of which tools are to be used and why they are appropriate; Clear description of how data collected will be analysed.	30	22
The development methods and tools are described well. However, the reasoning for selecting these tools over others could be expanded to provide stronger justification. How data will be collected and analysed is mentioned		
Resources / Planning: List of any deliverables; Clear diagram showing both timing and resource use; Completed ethics form;	15	12

Limited and relevant appendices.		
Deliverables are listed. Clear Gantt chart showing each tasks to be completed. Ethics form completed.		
Document Presentation: Correct spelling, grammar and punctuation; Flow of narrative/fluency; Coherence; Word processed ; Correct use of referencing with bibliography; Strict word limit		
The document is well structured and well-presented with correct spelling, good flow and adheres to word limit. The flow of narrative and coherence are good ,but could be improved by refining transitions between sections. Greater inclusion of peer-reviewed journals or authoritative books would enhance the quality of the references. Formatting would be improved. Additionally, referencing figures in the description would improve the quality of the document.	15	10
TOTAL	100	74

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