UNIVERSITY OF TWENTE.

Faculty of Electrical Engineering,
Mathematics & Computer Science

Bachelor EE Module 04
Antenna Project - Project Plan

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1 Introduction

A significant part of modern technology depends on the ability to send data from A to B through tin air. In this project, we are going to build an antenna to do just that: send information using electromagnetic waves over a certain distance. Before starting this project, a project plan was made, which we, project group Popov, present to you this way.

2 Problem Definition

2.1 Goal

The goal of this project is to design, construct and test an unidirectional antenna for transmitting electro magnetic waves over approximately 155 meters at an Ultra High Frequency (UHF) of 433 MHz with high gain. [1]

2.2 Learning Aims

During this project this group will (among others) learn about...:

- ... the practical aspects of building an antenna;
- ... the Yagi-Uda array antenna;
- ... antenna resonance and it's connection to impedance;
- ... impedance matching in order to maximize radiation;
- ... balun (for balanced to unbalenced) and how to use it to maximise;
- ... the use of reflection to make a signal more unidirectional;
- ... reflection loss (also return loss) and ways to minimize the effects;
- ... account for differents in speed of light in different materials the transmission of signals between the transmission line and the antenna;
- ... the modeling of Antenna's and reflecting materials using software like MATLAB or 4NEC2;
- Using Maxwell's classical theory of electromagnetism to describe and evaluate electromagnetic fields and waves produced by electric charges. [2]
- Using force- and potential fields to calculate forces acting on charges that are stationary or moving at constant velocity. [2]
- Understanding and model how accelerating charges in antennas may be used to emit (send) and absorb (receive) electromagnetic waves (information). [2]
- Understanding electric fields inside linear, isotropic materials. [2]

2.3 Specifications

The antenna which will be build will be connected to the Quasar UK AM hybrid transmitter module QAM-TX1. The following specifications of the module are or might be important for building the external antenna for the module: [3]

- Working frequency 433.92 MHz (Ultra High Frequency)
- Data rate 200-3000 Hz
- Output impedance 50Ω

From these specifications and the requirements for the project assignment, it was determined that the antenna has to face to following specifications: [4]

- Frequency band: 433-434 MHz (Ultra High Frequency)
- Gain: >10dBi
- Directivity: >10dBi
- Polarisation: Linear
- Bandwidth: <40 MHz
- Impedance: 50Ω
- Front to back ratio: <3dBi
- HPBW/Horizontal: <60°
- HPBW/Vertical: <90°
- Impedance matched with a balun
- Can be tested with USB spectrum analyzer (Realteck RTL2832U)

Of which the most important criteria is that the antenna transmits a signal at the previously specified frequency. For this to be the case, the impedances have to be properly matched.

3 Antenna Choice

There are lots of different antennas, each optimized for different applications. Literature research was done to find the pros and cons of various different antennas. As the antenna needs to be directional for this project, a few antennas drop off like the circular antenna, since they propagate the signal in multiple directions. There are a few antenna's that meet our design criteria, which will be explained later on in the report. The antenna in this project needs to be directional in order to get more signal at the receiver antenna.

3.1 Axial-mode helical antenna

The helical antennas are named after their shape, which is a conductive wire (copper for example) bent in the shape of a corkscrew and equipped with a ground plate at the end. A helical antenna has two modes, normal mode and axial mode. Normal mode is omnidirectional and is thus not suited for this project. Axial mode is directional, however, all the dimension need to be almost perfect in order to get a proper gain. A slight deviation could render the antenna useless. Furthermore, is the antenna circularly polarized, which means that it will be easier to "aim" the antenna, since it can be rotated around its axis of propagation. Although this antenna could potentially have a high gain and high directivity, it is very hard to build with a small margin of error. [5][6]

3.2 Yagi-Uda antenna

The Yagi-Uda antenna consists of a dipole antenna, a reflector and one or more directors. The main element, from which the antenna is driven, is the dipole. The reflector and directors are parasitic elements which reflect or direct the transmitted energy in a specific direction. The reflector is placed behind the dipole and is slightly larger than the dipole since this physically makes it a better reflector and it makes the reflector inductive. Therefore, the voltage of the reflector induces a lagging current, which causes a phase distribution across the elements leading to an array which functions as a traveling wave antenna. The directors are placed in frond of the dipole and are smaller than the dipole which makes them capacitive. This causes wave propagation in the direction of the directors. In general, the more directors the antenna consists of, the higher gain the antenna has, but it decreases the bandwidth. Usually, a Yagi-Uda antenna has a bandwidth of 2-3 percent of its centre frequency. Since this is quite small, it is mostly being used for fixed frequency applications. The antenna has a very good directivity, with a typical gain that is limited to 20 dB. Building this antenna is not that difficult, the calculations on the other hand are. If carefully designed and calculated, this antenna could work perfectly.[7][8][9]

3.3 Horn antenna

A horn antenna consists of a wave guide and a flaring metal shaped like a horn. The horn can have many different shapes resulting in a great variety of horn antenna's. One of the most feasible horn for this project computational wise and building wise considering the means at hand is an antenna with a pyramidal horn. The main advantages of this antenna being it's a significant level of directivity and thus gain furthermore its good impedance matching. The shape of the waveguide and flaring horn increases its directivity making it utilizable for long distance applications. A large aperture is needed to reach greater levels of gain which can reach up to 20 dB. The reason being that the aperture of the horn remains constant in terms of physical dimensions, but increases in terms of the number of wavelengths. The gain and directivity increase as the frequency used by the antenna increases, while the beam width decreases. This is due to the aperture of the antenna remaining constant whiles the number of wavelengths increases.A downside of this antenna though is the fact that the flare angle and length of flare should not be small in order to attain the desired gain.[10][11]

3.4 Conclusion: Yagi-Uda Antenna

After considering the different types, the Yagi-Uda antenna turned out to be most suitable according to the design requirements. The main reasons for this decision are the higher directivity and the fact that it is easier to build than the other antenna's.

4 Balun

To properly send a signal with a dipole antenna the two poles need to be in opposite phase, since the current in both poles is opposite. If the signal in both sides is in equal phase, the signals will cancel each other, which does not make for a very good antenna. Thus, to ensure it will work properly, a balun is needed. A balun reverses the phase of one of the poles, such that they will not cancel each other. A quick and easy to build design for a balun consists of two coax cables of different lengths. The input should be split into two coaxial cables. One cable should have a length equal to 1 wavelength of the signal, while the other is half a wavelength longer. This way the current is in the same direction in the parts of the dipole which are radiating. When calculating the wavelength do note that the speed of light is slightly different in a coaxial cable, it is usually around $\frac{2}{3}$, for the actual value the datasheet of the used coaxial cable can be used to find the actual value for that specific cable.

5 Connecting antenna to transmitter module

5.1 Maximum power transfer

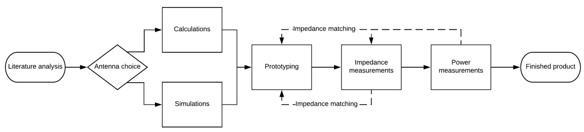
To ensure that the maximal amount of power is being transferred, the impedance of the load has to be matched with the impedance of the source. The source impedance should be equal to the complex conjugate of the load impedance, so only the real (resistive) part remains [12]. If the load impedance is larger than the source impedance, then reflection can occur. This reflection then distorts the signal [13]. If the load impedance is lower, then there is excessive power loss.

5.2 Impedance matching

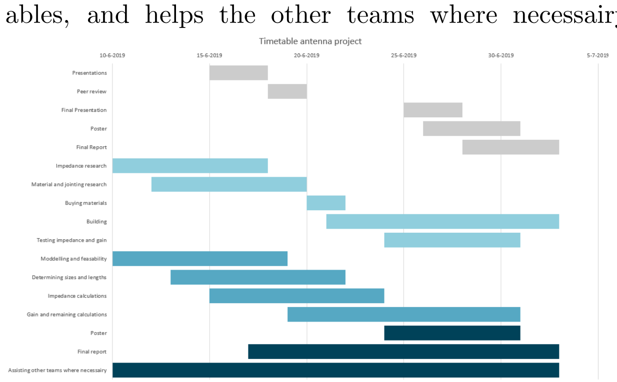
Impedance matching can be done by building an LC-circuit. This LC-circuit should minimize the imaginary part of the impedance so that most power will be radiated out of the antenna [14] [15]. Another way to achieve impedance matching is using a balun, the nice thing about this is that it can be adjusted if for example the inductance value of a coil is not correct.

To get the impedance of the antenna, a VNA (Vector Network Analyser) can be used. This produces a smith chart, which shows the input impedance of the antenna [15]. The impedance of a coaxial cable is a characteristic of that certain cable, so only the length determines the impedance of the transmission line. Then an appropriate balun can be made for those specific impedances.

6 Task Division



The block diagram shows the preferred order in which the tasks are to be completed. To monitor the progression, Bart has been chosen as group leader. To be able to divide the tasks for this project over the group members, the group is split up in three separate teams. The total group now consists of a research team (Bart and Hidde), a building team (David, Martin, Jan and Stijn) and an overlapping team (Marlin, Daan and Jeroen). The main tasks for the investigating team are looking for equations/relations and working out the calculations. As the name suggests, the building team is responsible for creating the antenna, balun and transmission line. Lastly, the overlapping team focuses on the deliverables, and helps the other teams where necessairy.



The Gantt chart shows the tasks of the different teams. The light blue tasks are for the building team, the "regular" blue tasks are for the researching team and the dark blue tasks are for the overlapping team. The grey part resembles the time allocated for working on the deliverables. These tasks are for all three teams

For the project there are 4 team deliverables: 1; A project plan 2; A peer review report on the antenna design 3; A paper on the final design and its validation 4; A poster on the improved design and its validation The contribution of the tasks to a deliverable can be seen in the chart:

References

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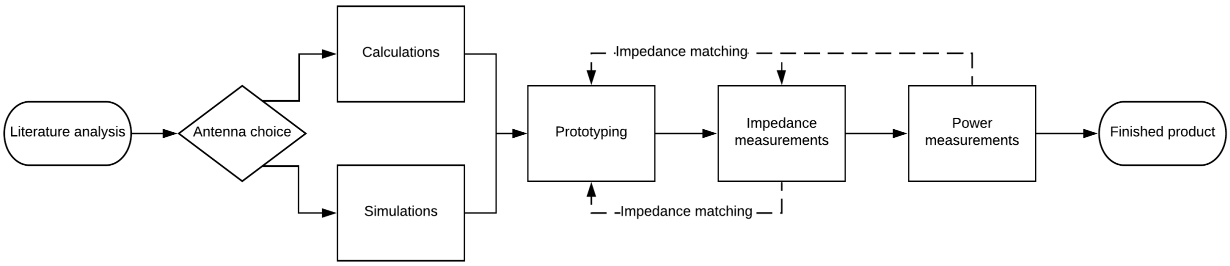
7 appendix

Block diagram of the designing process



Timetable of the antenna project