Software Defined Radio Channel emulator for Satellite based communication systems initial report

George Burns
dept. Electrical and Electronic Engineering
University of Bristol
Bristol, United Kingdom
george.burns.2001@bristol.ac.uk

***Abstract*—This report will detail the effects simulated in the Software Defined Radio (SDR) channel emulator that I will be using Python programming language.**

I. Introduction

In this section there will be a list of the effects that will be detailed in this report and simulated in the Channel Emulator. Satellite communications come under attenuation both complex and real. Most channel emulators for these effects are expensive and hard to implement however the aim of this projects is to construct software that simulates these effects.

Using [1] as a basic reference point a basic model can be constructed. As shown in Figure 1.

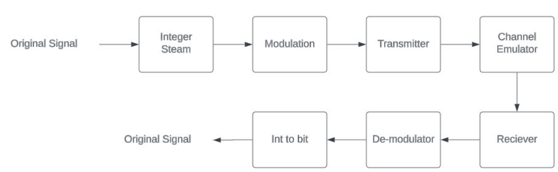


Fig. 1: Full System Model

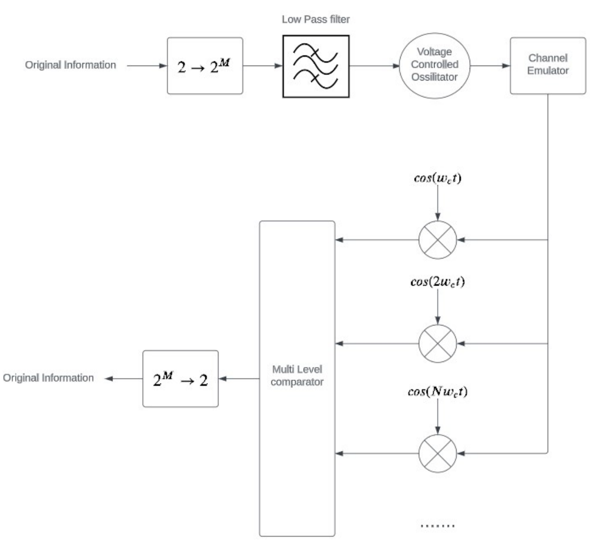
The Majority of the work will be focused on the Channel Emulator part of the system.

The Emulator will primarily focus on the following effects; Free space loss, Atmospheric Effects, Ionospheric Effects, Rain Fade, Noise Temperature, and the effects of Orbit. All of these effects have a significant impact on the channel. They are both complex and real degradation. This means that for an electromagnetic wave represented as $Ae^{jwt+\theta}$, the channel will degrade the amplitude (A), the phase (θ), and the frequency ($w = 2\pi f$), where f is the frequency and $j = \sqrt{-1}$ is the imaginary number.

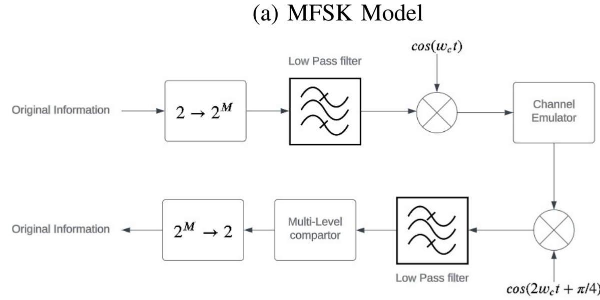
These are also dependent on time as during the orbital period of the satellite both slant angle [1] and if the orbit is elliptical [2] the distance can also change, these effects will be detailed in section (PUT SECTION HERE)

II. Modulation

A large variety of modulation schemes are used in satellite communications [3]. For this project I will aim to employ multi-level frequency shift keying (MFSK) and multi-level amplitude shift keying (MASK) shown in both Figure 2. This was a good way to progress onto more complicated modulation schemes like quadrature amplitude modulation (QAM).



(a) MFSK Model



(b) MASK Model

Fig. 2: Modulation Schemes diagrams

III. Free Space loss

Equation 1 is used to model free space loss, r_s is usually just distance on a terrestrial plane however slant path needs to be accounted for which can be calculated using Equation 2.

$$A_{fs} = \frac{A_r A_t}{\lambda^2 r_s^2} \tag{1}$$

Where A_{fs} is free space loss, A_r and A_t are the area of transmitter and receiver antenna respectively λ is wavelength and r_s is slant path.

$$r_s = \frac{hsin(\psi)}{sin(\frac{\pi}{2} + \theta)} \tag{2}$$

Where h is the height above Earth, r_e is Earth's radius $6378Km$, θ is the elevation angle and ψ is the central angle determined by equation 3.

Thus as the satellite changes distance (slant path r_s) the free space attenuation changes. Other effects on this equation could be the frequency f and thus the wavelength λ of the radio frequency (RF) signal changing though the ionosphere mentioned in section X.

$$\psi = cos^{-1}(\frac{r_e}{h}(sin(\frac{\pi}{2} + \theta)) - \theta \tag{3}$$

IV. Atmospheric Attenuation

Effects of the atmosphere along the slant path r_s must be considered when modelling RF propagation through Earth's atmosphere, its effects can be mathematically modelled as having distinct layers. The full mathematical model is complex so the goal was to use the International Telecommunications Union's curve fitting process. Using [4] to gain γ_o the oxygen attenuation and γ_w the water attenuation we can get an expression for atmospheric attenuation from [5] to form equation 4.

$$A_a = \frac{h_o\gamma_o + h_w\gamma_w}{sin(\theta)} \tag{4}$$

Where A_a is the atmosphere attenuation in dB, h_0 is the oxygen height and h_w is the water vapour height both obtained by using the curve fit equation found in [5].

V. Rain Attenuation

Hydrometeors are small water particles in the atmosphere can cause RF attenuation and thus must be accounted for in the model ITU provides a suitable model where [6] provides the $R_{0.001}$ rain statistic. Then in conjunction with [5] we can develop the rain model necessary.

VI. Scintillation and multipath fading

Multipath and Scintillation can both be accounted for using ITU recommendations in [5] both for $\theta > 5$ and $\theta < 5$. These are all dependent on location and measurements from that area for parameters such as average humidity and temperature.

VII. Noise temperature

The noise equation (equation 5) states that noise is directly proportional to temperature.

$$N_o = kTB \tag{5}$$

Where N_o is noise per bit, k is Boltzman's constant, $T[K]$ is temperature in Kelvin and $B[Hz]$ is bandwidth in Hertz.

Temperature can effected by a large array of systems and are detailed further in [7], where detailed models are produced and thus a more accurate model of T from equation 5 can be formed.

References

[1] J. S. Seybold, *Introduction to RF propagation*. Hoboken, N.J: Wiley, 2005.

[2] I. Ali, P. G. Bonanni, N. Al-Dhahir, and J. E. Hershey, *Doppler Applications in LEO Satellite Communication Systems*, 1st ed. Springer Publishing Company, Incorporated, 2013.

[3] A. Smith, M. Evans, and J. Downey, "Modulation classification of satellite communication signals using cumulants and neural networks," in *2017 Cognitive Communications for Aerospace Applications Workshop (CCAA)*. Cleveland, OH, USA: IEEE, Jun. 2017, pp. 1–8. [Online]. Available: http://ieeexplore.ieee.org/document/8001878/

[4] "RECOMMENDATION ITU-R P.676-5 - Attenuation by atmospheric gases."

[5] "RECOMMENDATION ITU-R P.618-7 - Propagation data and prediction methods required for the design of Earth-space telecommunication system."

[6] "RECOMMENDATION ITU-R P.837-1 - characteristics of precipitation for propagation modelling."

[7] "RECOMMENDATION ITU-R P.372-16 - Radio noise*."