RADIO WAVE PROPAGATION MECHANISMS

Fundamentals and Applications

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Abstract

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Acronyms

CNN Convolutional Neural Networks. 3, 5

EHF Extremely High Frequency. 3

EM Electromagnetic. 2

HF High Frequency. 3

IEEE Institute of Electrical and Electronics Engineers. 2, 3

ITU International Telecommunication Union. 2

LF Low Frequency. 3

MF Medium Frequency. 3

NN Neural Networks. 3, 5

RNN Recurrent Neural Networks. 3, 5

RX Receive. 3

SHF Super High Frequency. 3

THF Tremendously High Frequency. 3

TX Transmission. 3

UHF Ultra High Frequency. 3

VHF Very High Frequency. 3

VLF Very Low Frequency. 3

1 Introduction

1.1 Background

1.2 Objectives

1.3 Summary of Contributions

1.4 Outline

2 Fundamentals of Radio Wave Propagation

This section will briefly describe the fundamentals of radio waves and their propagation mechanisms. In order to describe radio waves, the Electromagnetic (EM) waves should be described since radio waves are a small subset of EM waves. When electrons move through a conductor medium, they create EM waves that can propagate through in space. These waves can display different characteristics depending on the fundamental properties of the wave, i.e. their wavelength. Figure 1 depicts the EM spectrum as a function of wavelength (λ) and frequency (f).

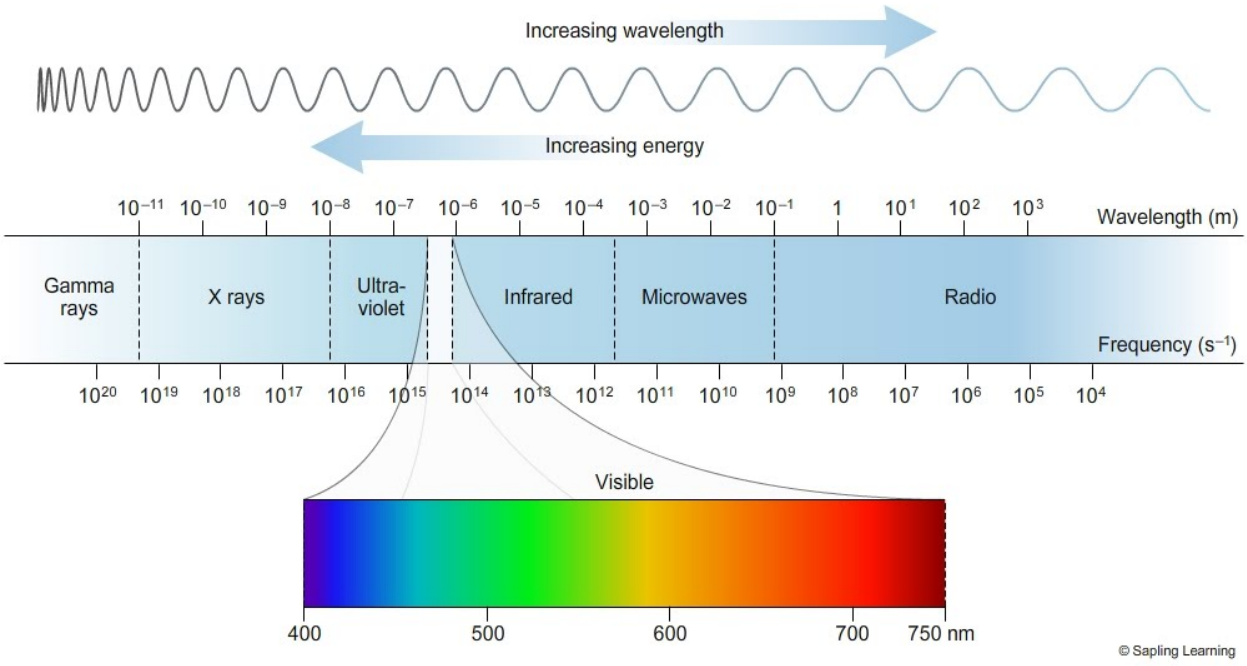

Figure 1: Electromagnetic Spectrum

As it can be seen in Figure 1, not only does radio waves form the lowest frequency band of the spectrum, but it also contains the most diverse frequency range amongst other EM bands. This diversity given a rise to a need of subdividing the radio wave band into smaller bands due to the fact that the waves display significantly difference physics. Thus, the radio waves was subcategorized into smaller bands by different standards. However, one of the most common standard was formed by IEEE [1]. Section 2 and section 2 tabulate the categories proposed by International Telecommunication Union (ITU) and IEEE, respectively.

Band Number	Symbols	Frequency Band	Wavelength Range
4	Very Low Frequency (VLF)	3 to 30 kHz	10 to 100 km
5	Low Frequency (LF)	30 to 300 kHz	1 to 10 km
6	Medium Frequency (MF)	300 to 3000 kHz	100 to 1000 m
7	High Frequency (HF)	3 to 30 MHz	10 to 100 m
8	Very High Frequency (VHF)	30 to 300 MHz	1 to 10 m
9	Ultra High Frequency (UHF)	300 to 3000 MHz	100 to 1000 cm
10	Super High Frequency (SHF)	3 to 30 GHz	10 to 100 cm
11	Extremely High Frequency (EHF)	30 to 300 GHz	1 to 10 cm
12	Tremendously High Frequency (THF)	300 to 3000 GHz	0.1 to 1 mm

Table 1: Radio Wave Channel Divisions by ITU

Band Designation	Frequency Band	Wavelength Range
HF	3 to 30 kHz	10 to 100 km
VHF	30 to 300 kHz	1 to 10 km
UHF	300 to 3000 kHz	100 to 1000 m
L Band	3 to 30 MHz	10 to 100 m
S Band	30 to 300 MHz	1 to 10 m
C Band	300 to 3000 MHz	100 to 1000 cm
X Band	3 to 30 GHz	10 to 100 cm
K_u Band	30 to 300 GHz	1 to 10 cm
K Band	30 to 300 GHz	1 to 10 cm
K_a Band	30 to 300 GHz	1 to 10 cm
V Band	30 to 300 GHz	1 to 10 cm
W Band	30 to 300 GHz	1 to 10 cm
G Band (mm)	30 to 300 GHz	1 to 10 cm

Table 2: Radio Wave Channel Divisions by IEEE

2.1 Radio Wave Propagation Mechanisms

2.1.1 Reflection

2.1.2 Diffraction

2.1.3 Scattering

2.2 Path Loss, Shadowing and Fading

Transmission (TX) Receive (RX) Path loss is caused by dissipation of the power radiated by the transmitter as well as effects of the propagation channel. Path loss models generally assume that path loss is the same at a given transmit-receive distance1. Shadowing is caused by obstacles between the transmitter and receiver that absorb power. When the obstacle absorbs all the power, the signal is blocked.

Variation due to path loss occurs over very large distances (100 – 1000 meters), whereas variation due to shadowing occurs over distances proportional to the length of the obstructing object (10-100 meters in outdoor environments and less in indoor environments). Since variations due to path loss and shadowing occur over relatively large distances, this variation is sometimes refered to as **large-scale propagation effects** or **local mean attenuation**.

2.3 Indoor Radio Wave Propagation Models

3 Fundamentals of Function Approximation and Neural Networks (NN)

Neural Networks (NN), Recurrent Neural Networks (RNN) and Convolutional Neural Networks (CNN)

3.1 Neural Networks (NN)

3.2 Convolutional Neural Networks (CNN)

3.3 Recurrent Neural Networks (RNN)

References

[1] JA Bruder, JT Carlo, JH Gurney, and J Gorman. Ieee standard letter designations for radar-frequency bands. *IEEE Aerospace & Electronic Systems Society*, pages 1–3, 2003.