

Antennas and Propagation of Waves Connecting the World Wirelessly

K. Maidanov¹, H. Fratlin²

^{1,2}Department of Electrical and Computer Engineering, Ben-Gurion University, Beer Sheva, Israel

KEYWORDS:

Omnidirectional antennas,
Frequency modulation,
Amplitude modulation,
Phase modulation,
Antenna polarization,
Modulation techniques

ARTICLE HISTORY:

Received 14.01.2023
Revised 13.02.2023
Accepted 21.03.2023

DOI:

<https://doi.org/10.31838/NJAP/05.01.01>

ABSTRACT

In the realm of modern communication, the invisible force behind the seamless transfer of information is antennas and propagation. These technological marvels serve as bridges, enabling wireless communication across vast distances. From cell phones to satellite communication, from Wi-Fi routers to radio broadcasting, antennas play a pivotal role in shaping our interconnected world. In this article, we delve into the fascinating world of antennas and propagation, exploring their mechanisms, applications, and significance.

Author's e-mail: frantlin.h@gmail.com, maidanov.k@gmail.com

How to cite this article: Maidanov K, Fratlin H. Antennas and Propagation of Waves Connecting the World Wirelessly. National Journal of Antennas and Propagation, Vol. 5, No. 1, 2023 (pp. 1-5).

INTRODUCTION

Understanding Antennas

At its core, an antenna is a device designed to transmit or receive electromagnetic waves. These waves carry information encoded in the form of radio frequency (RF) signals. Antennas come in various shapes and sizes, each tailored for specific applications and operating frequencies. They can be as small as the antennas in your smartphone or as large as the towering structures used for broadcasting^[1-21] as shown in Fig. 1.

Types of Antennas

1. Dipole Antennas

These are perhaps the simplest form of antennas, consisting of two conductive elements aligned along the same axis. Dipole antennas are widely used in radio and television broadcasting due to their omnidirectional radiation pattern.^[22-35]

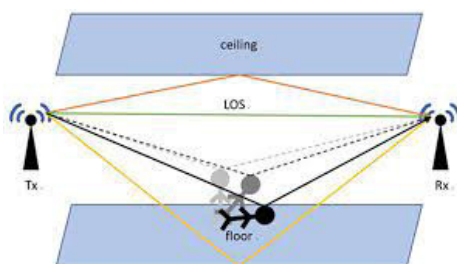


Fig. 1: LoS levels

2. Yagi-Uda Antennas

Also known as beam antennas, Yagi-Uda antennas are characterized by multiple parallel elements, including a driven element, reflector, and one or more directors. They offer high gain and directional capabilities, making them ideal for long-distance communication.

3. Patch Antennas

Commonly found in Wi-Fi routers and RFID systems, patch antennas are compact and offer directional radiation patterns. They are constructed on printed circuit boards, making them cost-effective and easy to integrate into electronic devices.

4. Parabolic Reflectors

These antennas consist of a curved reflective surface (parabola) with an antenna feed positioned at its focal point. Parabolic reflectors are renowned for their high gain and narrow beamwidth, making them suitable for point-to-point communication, such as satellite links and microwave links.^[36-45]

PROPAGATION OF ELECTROMAGNETIC WAVES:

Propagation refers to the manner in which electromagnetic waves travel from the transmitter to the receiver as shown in Fig.2. Understanding propagation is crucial for optimizing the performance of wireless communication systems. Several factors influence propagation, including

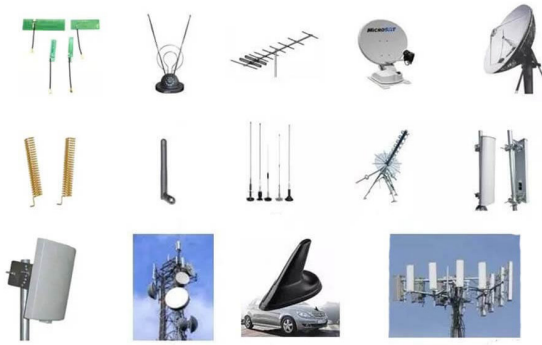


Fig. 2: Different types of antenna

frequency, distance, terrain, and environmental conditions.^[46-52]

KEY PROPAGATION MECHANISMS

1. Line-of-Sight (LOS) Propagation

In LOS propagation, the transmitter and receiver have a clear, unobstructed line of sight. This mechanism is prevalent in microwave communication and satellite links, where signals travel directly from the transmitter to the receiver without significant obstacles.

2. Multipath Propagation:

In environments with obstacles or reflective surfaces, such as urban areas or indoor spaces, signals can undergo multipath propagation. This occurs when signals take multiple paths to reach the receiver due to reflections, diffraction, and scattering as shown in Fig.3. While multipath propagation can cause signal fading and distortion, it is also exploited in techniques like diversity reception and MIMO (Multiple Input Multiple Output) to improve reliability and data rates.^[53-61]

3. Ionospheric Propagation:

Ionospheric propagation occurs in the Earth’s ionosphere, a region of the upper atmosphere where ionization by

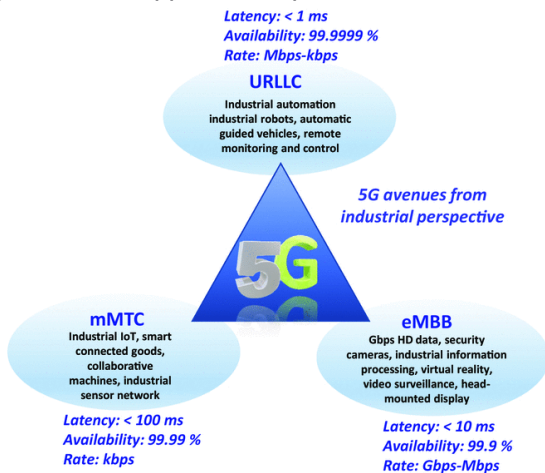


Fig. 3: 5G antenna radiation levels

solar radiation affects the propagation of radio waves. This phenomenon enables long-distance communication via skywave propagation, where signals are reflected back to Earth by the ionosphere. It is utilized in shortwave radio broadcasting and over-the-horizon radar.

4. Tropospheric

Propagation: Tropospheric propagation involves the bending of radio waves within the troposphere, the lowest layer of the Earth’s atmosphere. Atmospheric conditions, such as temperature inversions and humidity gradients, can cause signal ducting, where signals are trapped and propagated over long distances beyond the horizon. Tropospheric propagation is utilized in microwave communication and long-range radio links as shown in Fig. 4.

APPLICATIONS AND SIGNIFICANCE:

The significance of antennas and propagation extends across various domains, encompassing telecommunications, broadcasting, navigation, remote sensing, and more. Here are some notable applications:

- ♦ **Wireless Communication:** Antennas facilitate wireless communication in cellular networks, Wi-Fi systems, Bluetooth devices, and IoT (Internet of Things) devices, enabling seamless connectivity and data exchange. Wireless communication refers to the transmission of data, information, or signals over a distance without the need for physical cables or wires. This mode of communication relies on electromagnetic waves to carry information through the air or vacuum. Wireless communication has become ubiquitous in modern society, enabling seamless connectivity and communication across various devices and systems.

One of the key advantages of wireless communication is its ability to provide flexibility and mobility. Users can access communication networks and services from virtually anywhere, allowing for greater convenience and accessibility. Wireless communication technologies such as Wi-Fi, Bluetooth, cellular networks, and

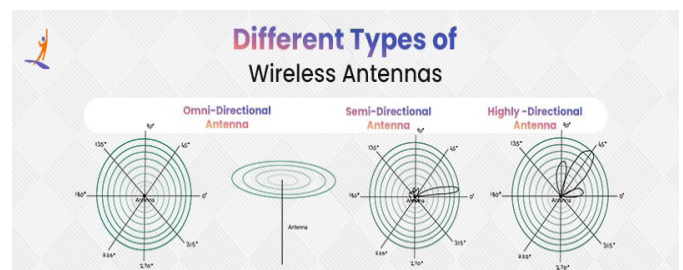


Fig. 4: Different types of antennas pattern

satellite communication systems facilitate a wide range of applications, including mobile telephony, internet access, IoT (Internet of Things), smart devices, and more.

Wireless communication systems typically consist of transmitters, receivers, antennas, and signal processing components. Transmitters convert electrical signals into electromagnetic waves, which are then transmitted through the air. Receivers capture these waves and convert them back into electrical signals for processing. Antennas play a crucial role in transmitting and receiving signals efficiently, while signal processing techniques are used to enhance signal quality, manage interference, and ensure reliable communication.

Overall, wireless communication has revolutionized the way people connect, communicate, and interact in the modern world, enabling seamless connectivity, mobility, and access to information anytime, anywhere.

- ♦ **Broadcasting:** From AM/FM radio to television broadcasting, antennas are instrumental in delivering audio and video content to millions of households worldwide as shown in Fig.5.
- ♦ **Satellite Communication:** Antennas are essential components of satellite communication systems, enabling the transmission of signals between ground stations and orbiting satellites for applications such as telecommunication, weather monitoring, and global positioning. Satellite communication refers to the transmission of signals between Earth-based stations and satellites orbiting in space. This mode of communication utilizes artificial satellites to relay signals over long distances, enabling global connectivity and communication services.

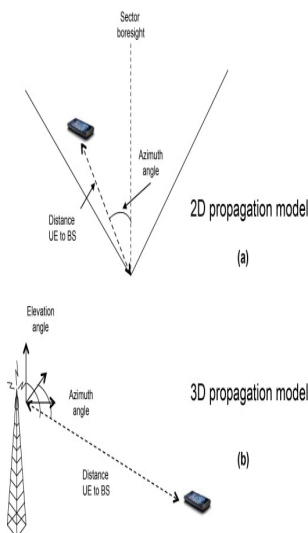


Fig. 5: Propagation models

Satellite communication plays a crucial role in various applications, including telecommunications, broadcasting, navigation, weather monitoring, and remote sensing.

Satellite communication systems typically consist of three main components: ground stations, satellites, and user terminals. Ground stations are equipped with antennas and transceivers to communicate with satellites in orbit. Satellites act as relay stations in space, receiving signals from ground stations, amplifying them, and retransmitting them to other ground stations or user terminals. User terminals, such as satellite phones, television receivers, and navigation devices, receive signals from satellites to access communication services.

One of the key advantages of satellite communication is its ability to provide wide coverage and reach remote or inaccessible areas where traditional terrestrial communication infrastructure is impractical or unavailable. Satellite communication systems offer reliable and scalable communication solutions for various applications, including telephony, internet access, broadcasting, disaster relief, and military communications.

Despite its advantages, satellite communication also faces challenges such as signal latency, limited bandwidth, and susceptibility to interference. Advances in satellite technology, including high-throughput satellites, frequency reuse techniques, and signal processing algorithms, continue to improve the efficiency and performance of satellite communication systems, making them essential components of modern telecommunications infrastructure.

- ♦ **Radar Systems:** Radar systems rely on antennas to transmit and receive radio waves for purposes such as air traffic control, weather monitoring, military surveillance, and navigation [62]-[63]. Radar (Radio Detection and Ranging) systems are essential tools used for detecting, tracking, and identifying objects in the surrounding environment by emitting radio waves and analyzing the echoes reflected back from those objects. These systems find widespread use in military, aerospace, meteorology, maritime navigation, air traffic control, and automotive applications.

Radar systems operate based on the principle of sending out short pulses of electromagnetic waves and measuring the time it takes for the waves to return after bouncing off objects in the path of the radar beam. By analyzing the characteristics of the reflected signals, such as their

time delay, amplitude, phase, and Doppler shift, radar systems can determine the range, speed, direction, and size of objects within their detection range.

Modern radar systems employ advanced signal processing techniques, such as pulse compression, frequency modulation, and digital beamforming, to enhance detection capabilities, improve resolution, and reduce interference. Additionally, radar systems can operate in various frequency bands, including microwave,

millimeter-wave, and even optical frequencies, depending on the application requirements.

Overall, radar systems play a critical role in enhancing situational awareness, providing early warning, facilitating navigation and surveillance, and enabling a wide range of civilian and military applications. Continued advancements in radar technology promise to further improve the performance, versatility, and reliability of these systems in diverse operational environments as shown in Table. 1 and 2.

Table 1: Overall review of the crucial parameters of the antennas

Basic Antenna Type	Applications	Inherent Band-width	Gain Pattern*	Multipath Rejection	Interference Rejection	Phase Center Stability	Size	Profile	Weight	Cost*
<i>Patch antenna</i>	Most	Narrow	Strict	Medium	Medium	Medium to poor	Small to medium	Low	Medium	Low if single band
<i>Quadrifilar helix</i>	Handheld and small platform	Narrow	Somewhat strict	Medium	Medium	Poor	Small to medium	High	Small	Medium
<i>Cross slot/dipole</i>	Medium/large platform	Narrow	Strict	Medium	Medium	Medium	Medium	Low	Medium	Medium
<i>Planar spiral**</i>	All but handheld applications	Very wide	Strict	Medium to high	Medium	Very good	Medium	Low to medium	Medium	Medium
<i>4-element ring array</i>	All but handheld applications	Narrow to wide	Strict	Medium to high	Medium to high	Poor to good	Generally large	Low to high	Medium to heavy	Medium to high
<i>Traveling-wave (TW) antenna**</i>	All applications	Very wide	strict	Medium to high	Medium	Good to very good	Medium to small	Low	Medium	Medium
<i>Adaptive 2-element array</i>	Handheld and small platforms	Narrow	Not strict	Medium	Medium	Poor	Small to medium	Low to high	Light	Low to medium
<i>Adaptive multi-element circular array</i>	Medium to large platforms, mostly military	Narrow to wide	Very strict	High	Very high	Medium	Medium to large	Low to medium	Heavy	Very high

* Large changes in a few years are expected. **Spiral antenna and TW antenna overlap each other considerably.

Table 2: Report on Path loss and Power

Path Loss Exponent (n)	Power (W) for -80 dBm	Power (W) for -100 dBm
2.4	0.0385	0.0004
2.5	0.0967	0.0010
2.6	0.2425	0.0024
2.7	0.6084	0.0061
2.8	1.5262	0.0153
2.9	3.8285	0.0383
3.0	9.6037	0.0960
3.1	24.0909	0.2409
3.2	60.4321	0.6043
3.3	151.5942	1.5159
3.4	380.2745	3.8027
3.5	953.9198	9.5392

CONCLUSION

In conclusion, antennas and propagation of waves are fundamental aspects of modern communication, radar, and sensing systems. Antennas serve as the interface between electronic devices and the electromagnetic spectrum, enabling wireless communication, radar detection, and remote sensing. Understanding antenna design principles, propagation mechanisms, and signal processing techniques is crucial for optimizing system performance, maximizing coverage, and ensuring reliable communication. Advances in antenna technology, propagation modeling, and signal processing continue to drive innovation in wireless communication, satellite navigation, radar systems, and beyond, shaping the future of interconnected, high-speed, and reliable communication networks. Antennas and propagation form the backbone of modern wireless communication,

enabling the exchange of information across vast distances with remarkable efficiency and reliability. As technology continues to advance, the development of innovative antenna designs and propagation techniques will play a pivotal role in shaping the future of connectivity, bringing the world closer together in an era of seamless communication.

REFERENCES

1. "Cut the Cord: Wireless Power Transfer", *its Applications and its limits*, pp. 1-11.
2. "Wireless Power Transmission Circuit and its Working system", *Visited Time*, vol. 11, 01 21.
3. "Wireless Charging Systems: Pros and Cons", *Visited Time: 03-05-21*, vol. 09, pp. 2010-2015, November 2015.
4. M. M, "High-Range Wireless Power Legal Notices & Trademarks", *visited Time: 28-04-21*, vol. 11, November 2017.
5. Rahul Charith et al., Wireless Power Transfer Circuit | Wireless Mobile Charger, December 2017.
6. "Common environmental noise levels | CHC. (n.d.)", *Centre for hearing and Communication Connect to life*, vol. 09, pp. 2010-2015.
7. S. Patel and S. Patel, Researchers Demonstrate 120-kV Wireless Charging System for Electric Vehicles, November 2018.
8. Das Suprabhat, "Review Paper on Wireless Power Transmission for Charging Mobile Devices", *International Journal of Engineering and Computer Science*, vol. 6, pp. 20751-20755, 2017.
9. "What is Microphone Bias Voltage?", *Learningaboutelectronics.com*, vol. 09, 2019.
10. P. Mantione, *The Fundamentals of Amplitude and Loudness*, August 2018.
11. Philip Mantione, *Design of Wireless Power Transfer System via Magnetic Resonant Coupling at 13.56MHz*, [online] Available: <https://theproaudiofiles.com/amplitude-and-loudness/>.
12. Sah Ajay, *Design of Wireless Power Transfer System via Magnetic Resonant Coupling at 13.56MHz*, 2013.
13. T. F. Fadel Firdaus and W. B. Pramono, "Design of wireless battery charger using near-field induction method", *2015 9th International Conference on Telecommunication Systems Services and Applications (TSSA)*, pp. 1-5, 2015.
14. E. Jordan and K. G. Balmain, *Electromagnetic Waves and Radiating Systems*, 1968.
15. J. Jiang, "Audio processing with channel filtering using DSP techniques", *2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC)*, pp. 545-550, 2018.
16. Hua Li, Yingxue Zhang, Tingting Pan and Jing Sun, "A research on electromagnetic induction of electromagnetic tomography object field", *2009 Chinese Control and Decision Conference*, pp. 5181-5184, 2009.
17. M. Garg, D. Gera, A. Bansal and A. Kumar, "Generation of electrical energy from sound energy", *2015 International Conference on Signal Processing and Communication (ICSC)*, pp. 410-412, 2015.