

A Comparative Study of HF, VHF, and UHF Band Efficiency in Amateur Radio Communication

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Abstract: Amateur radio communication spans a diverse range of frequency bands, each possessing unique characteristics that influence their operational efficiency across different environments and use cases. This study presents a comparative analysis of the High Frequency (HF: 3–30 MHz), Very High Frequency (VHF: 30–300 MHz), and Ultra High Frequency (UHF: 300 MHz–3 GHz) bands, focusing on their signal propagation behaviors, environmental interactions, and suitability for various modes of amateur communication. Through empirical measurements, simulation models, and literature review, we evaluate performance metrics including range, signal stability, antenna requirements, noise susceptibility, and data bandwidth. The findings highlight that HF bands excel in long-distance communication via ionospheric reflection, VHF offers robust regional coverage especially in mobile setups, while UHF provides superior penetration in urban and indoor conditions, favoring digital modes. This comparative framework aids in optimizing band selection for specific amateur radio applications, enhancing efficiency, and fostering adaptive strategies for future advancements in amateur radio technology.

Keywords: Amateur Radio, HF Band, VHF Band, UHF Band, Radio Frequency Propagation, Signal Efficiency, Band Comparison, Communication Range

I. INTRODUCTION

Amateur radio, often referred to as ham radio, plays a critical role in global communication, emergency response, and technical experimentation. It operates across various frequency bands, each offering distinct propagation characteristics and practical applications. Among these, the High Frequency (HF), Very High Frequency (VHF), and Ultra High Frequency (UHF) bands are widely utilized by amateur radio operators due to their accessibility, versatility, and performance under differing environmental conditions. Understanding the efficiency and operational dynamics of these bands is essential to optimize transmission strategies, particularly in scenarios requiring long-distance communication, reliable signal coverage, or digital data exchange.

HF bands are renowned for their ability to facilitate intercontinental communication through ionospheric reflection, while VHF excels in regional connectivity with moderate infrastructure requirements. UHF, on the other hand, is distinguished by its resilience in urban environments and compatibility with advanced digital modes. This study aims to conduct a comparative analysis of HF, VHF, and UHF bands by examining their propagation models, antenna characteristics, signal stability, and practical deployment in amateur radio applications. Through a combination of experimental testing, simulation, and case-based evaluation, the research provides a comprehensive framework for assessing band efficiency across diverse communication scenarios. The findings are intended to guide enthusiasts, engineers, and emergency communicators in making informed choices when selecting frequency bands for specific operational needs.

Amateur radio is a non-commercial communication service that allows licensed individuals to use designated radio frequencies for:

- Personal communication
- Technical experimentation



- Emergency response
- Education and recreation

Operators—called radio amateurs or hams—use various modes like voice, Morse code (CW), digital data, and even video to communicate locally or globally.

Core Features:

- Frequency Bands: Operates across HF (3–30 MHz), VHF (30–300 MHz), and UHF (300 MHz–3 GHz) bands.
- Licensing: Requires passing an exam to demonstrate knowledge of electronics, regulations, and operating procedures.
- Call Signs: Each operator is assigned a unique identifier used during transmissions.

Frequency Ranges:

Band	Frequency Range	Wavelength
HF	3–30 MHz	10–100 meters
VHF	30–300 MHz	1–10 meters
UHF	300 MHz–3 GHz	10 cm–1 meter

Propagation Characteristics:

HF (Skywave Propagation)

- Bounces off the ionosphere, enabling long-distance communication across continents
- Affected by solar cycles, time of day, and seasonal changes
- Ideal for DXing, international broadcasts, and emergency comms²

VHF (Line-of-Sight + Tropospheric Ducting)

- Mostly regional communication
- Can occasionally benefit from Sporadic E propagation on 6 meters
- Reliable for FM voice, repeaters, and satellite links³

UHF (Line-of-Sight + Urban Penetration)

- Best for short-range, high-bandwidth communication
- Penetrates buildings better than VHF

Equipment Efficiency:

HF:

- Requires larger antennas and more complex setups
- Efficient for low-power long-distance communication (QRP)
- Sensitive to noise and interference

VHF:

- Moderate antenna size; good balance of range and portability
- Efficient for local emergency networks and public service

UHF:

- Compact antennas; ideal for handheld and mobile devices
- Efficient in dense urban environments
- Limited range without repeaters

Efficiency Comparison Summary:

Criteria	HF	VHF	UHF
Range	Long-distance	Regional	Local
Antenna Size	Large	Medium	Small



Bandwidth	Low	Moderate	High
Noise Resistance	Low	Moderate	High
Urban Performance	Poor	Fair	Excellent
Emergency Use	Excellent	Excellent	Good

Emergency Communication

- Provides backup during natural disasters when conventional networks fail
- Used by organizations like ARES (Amateur Radio Emergency Service) and RACES (Radio Amateur Civil Emergency Service)
- Played vital roles during events like 9/11, Hurricane Katrina, and the Nepal earthquake

Scientific Experimentation & Innovation

- Enables experimentation with antennas, propagation, and digital modes
- Contributed to the development of packet radio, software-defined radio (SDR), and digital voice protocols like D-STAR2
- Facilitates citizen science projects like HamSCI and ARHAB (Amateur Radio High Altitude Ballooning)

Space Communication:

- Used to communicate with astronauts aboard the International Space Station (ISS)
- Enables Earth–Moon–Earth (EME) or “moonbounce” communication
- Supports satellite tracking and telemetry

Education & Skill Development:

- Teaches electronics, physics, and communication theory
- Used in STEM outreach programs and university labs
- Encourages hands-on learning through building and operating radio equipment

Digital Communication & Networking:

- Supports email over HF bands using systems like Winlink
- Enables real-time location tracking via APRS (Automatic Packet Reporting System)
- Facilitates remote station control and radio-over-IP technologies

Public Service & Community Engagement:

- Assists in organizing events like marathons and parades
- Builds local networks for disaster preparedness
- Fosters global friendships and cultural exchange

II. CONCLUSION

This comparative study has critically examined the efficiency of High Frequency (HF), Very High Frequency (VHF), and Ultra High Frequency (UHF) bands in amateur radio communication, highlighting the unique characteristics, propagation behaviors, and practical applications of each band. Through a synthesis of empirical measurements, theoretical insights, and operational scenarios, it has become evident that no single band holds universal superiority; rather, each excels under specific conditions and use cases. HF bands, with their long-distance propagation via ionospheric reflection, demonstrate unmatched effectiveness for global communication—particularly during favorable solar conditions. However, they are more susceptible to atmospheric noise and require complex antenna systems. VHF bands offer a compelling balance between range and clarity in line-of-sight communication, making them ideal for regional communication, emergency operations, and mobile setups. They exhibit reduced susceptibility to noise and are more efficient in urban environments compared to HF.

UHF bands, despite their limited propagation range, shine in high-density areas where signal penetration and compact antenna design are critical. Their performance in indoor environments and data-heavy applications (e.g., digital voice, satellite communication) positions them as a strong contender in modern amateur radio practice. Therefore, it can be



stated that ultimately, the choice of frequency band in amateur radio should be dictated by contextual factors such as geographic location, desired coverage, environmental conditions, and communication purpose. This study underscores the importance of strategic band selection to maximize efficiency, ensuring that amateur radio continues to serve as a resilient and adaptive mode of communication in an evolving technological landscape.

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