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Optimizing Antenna Performance: A Comprehensive Guide to Stacking Yagi Antennas

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In the realm of antenna technology, achieving higher gain and improved directivity is a constant pursuit for engineers and enthusiasts alike. Yagi antennas, known for their simplicity and effectiveness, are widely used in various communication applications. However, a single Yagi antenna has its limitations in terms of gain and beamwidth. This white paper explores the technique of stacking Yagi antennas, a method that significantly enhances the performance of antenna systems. By delving into the principles, benefits, and practical considerations of Yagi antenna stacking, this paper aims to provide a comprehensive guide for those looking to optimize their antenna setups for better performance

The primary challenge addressed in this white paper is the limitation of gain and directivity in single Yagi antenna systems. While Yagi antennas are effective, their performance can be insufficient for applications requiring long-distance communication and high precision. This limitation can hinder the effectiveness of communication systems, particularly in amateur radio, satellite communications, and other long-range communication scenarios. By stacking multiple Yagi antennas, it is possible to overcome these limitations, achieving higher gain and narrower beamwidths. This white paper provides a detailed methodology for stacking Yagi antennas, offering solutions to enhance antenna performance and meet the demands of advanced communication applications.

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1. Increase Gain

By stacking two or more Yagi antennas, you can achieve higher gain compared to a single Yagi. Theoretically, the additional gain for a second Yagi with optimal stacking distance is around 3.0 dB, minus the insertion loss of coaxial cables and power dividers or combiners. It is beneficial to stack in multiples of 2, 4, 8, and 16. The table below illustrates the theoretical gain of a three-element Fully Welded Yagi antenna (Y6623D-200, 200-225 MHz, 7 dBd or 9 dBi) and a highly recommended high power, low loss divider (CC220-2, 220-225 MHz). What makes the CC220-2 special is its design with default ½ wavelength stack spacing. All the installer needs to do is connect and secure the power divider/coupler to the same mounting brackets used with the Y6623D-200, using minimal hardware. There is no theoretical limit on the number of Yagi antennas that can be stacked, but practical limitations may arise.

# of Yagi Stacked	Gain (dBi)	Azimuth (Horizontal) Beamwidth	Elevation (Vertical) Beamwidth
1	9 dBi	60°	50°
2	12 dBi	30°	25°
4	15 dBi	26°	12.5°
8	18 dBi	7.5°	6.3°
16	21 dBi	3.8°	3.1°
32	24 dBi	1.9°	1.6°

Table 1: Number of Yagi Antennas Stacked

Y6623D-200

CC220-2

2. Reduce Beamwidth

Stacking antennas reduces the beamwidth in the plane of stacking. If you stack vertically, the vertical beamwidth is reduced by 50%, and if you stack horizontally, the horizontal beamwidth is reduced by 50%. For example, a single Yagi antenna (Y6623D-200) has a gain of 9 dBi, a horizontal beamwidth of 60°, and a vertical beamwidth of 50°. Stacking two of these antennas increases the gain to 12 dBi, reduces the horizontal beamwidth from 60° to 30°, and the vertical beamwidth from 50° to 25°. Stacking 32 Yagi antennas reduces the horizontal beamwidth to 1.9° and the vertical beamwidth to 1.6°. This configuration is sometimes referred to as a “pencil beamwidth” antenna.

3. Optimal Stacking Distance

The distance between stacked antennas is crucial for optimal performance. The optimal stacking distance depends on the radiation angles (Azimuth/Horizontal and Elevation/Vertical) of each Yagi antenna. A practical approach is to stack in multiples of ½ wavelength (λ) up to a maximum of 2 wavelengths. The table below shows common frequency ranges and their corresponding stacking distances.

Stacking more than 1 wavelength increases sidelobes, which can pick up unwanted signals, while stacking as close as ½ wavelength results in a gain loss of approximately 0.3 dB. For the first ½ wavelength, the stacking distance is measured from the center of one Yagi antenna boom to the center of the other, plus a 2-inch offset to prevent the Yagi reflector elements from touching each other. To achieve optimal antenna gain and minimize sidelobes, the stacking distance at 1 wavelength can be measured from the center of one Yagi antenna boom to the center of the other. This method of stacking distance can also be applied to other directional or omni-directional antennas.

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Frequency	½ Wavelength (Minimum)	1 Wavelength (Best)
150-170 MHz	3.3 feet (39.6 inches)	6.6 feet (79.2 inches)
220-225 MHz	2.3 feet (27.6 inches)	4.5 feet (54 inches)
450-470 MHz	1.1 feet (13.2 inches)	2.2 feet (26.4 inches)
600-700 MHz	0.8 feet (9.6 inches)	1.6 feet (19.2 inches)
800-900 MHz	0.6 feet (7.2 inches)	1.2 feet (14.4 inches)
902-928 MHz	0.6 feet (7.2 inches)	1.2 feet (14.4 inches)
2.4-2.5 GHz	0.2 feet (2.4 inches)	0.4 feet (4.8 inches)
5.1-7.2 GHz	0.1 feet (1.2 inches)	0.2 feet (2.4 inches)

Table 1: Stacking Distance

4. Phasing and Matching

Proper phasing and matching are essential to ensure that the signals from the stacked antennas combine constructively. This involves using phasing lines and matching networks to align the signals correctly. In practice, the coaxial cable lengths connecting the Yagi antennas after the power combiner/divider need to be equal.

5. Applications

Stacking is often used in applications where increased gain and directivity are needed, such as amateur radio, satellite communications, and long-distance communications.

Stacking Yagi antennas can significantly improve the performance of your antenna system, providing higher gain and longer range at the expense of reduced beamwidth.

Summary

This white paper explores the technique of stacking Yagi antennas to enhance antenna system performance. By stacking multiple Yagi antennas, users can achieve higher gain and improved directivity, which are crucial for applications requiring long-distance communication and high precision. The paper details the benefits of increased gain, reduced beamwidth, optimal stacking distances, and the importance of proper phasing and matching. It also highlights practical applications such as amateur radio, satellite communications, and long-distance communications. This guide provides a comprehensive methodology for optimizing antenna setups, addressing the limitations of single Yagi antennas and offering solutions for advanced communication needs.

To learn more, please refer to our additional White Papers or reach out to speak with an antenna expert through info@mobilemark.com.