

ANTENNA ENGINEERING

Comprehensive Guide to DIY Antenna Engineering: Analyzing WA5VJB Kent Britain's High-Performance Designs

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The landscape of modern telecommunications often presents a paradox: while the complexity of digital signal processing has increased exponentially, the fundamental physical mechanisms of signal reception remain rooted in classical electromagnetics. For the amateur radio operator, the HDTV cord-cutter, or the microwave engineer, the work of **Kent Britain (WA5VJB)** represents a bridge between high-level electromagnetic theory and practical, cost-effective implementation. This article provides an exhaustive technical analysis of DIY antenna design, focusing on the "Cheap Yagi" philosophy and the precision of PCB Log Periodic (LP) antennas.

The Theoretical Foundation of Parasitic Arrays

To understand why the designs championed by Kent Britain are so effective, one must first grasp the mechanics of **parasitic elements**. Unlike a simple dipole where every element is connected to the transmission line, a Yagi-Uda antenna utilizes a single **Driven Element** coupled with several parasitic elements: the **Reflector** and one or more **Directors**.

The core mechanism is mutual induction. When the driven element radiates an electromagnetic field, it induces a current in the nearby parasitic elements. By carefully calculating the spacing and the length of these elements, an engineer can control the phase of the re-radiated energy. In a Yagi configuration, the reflector is typically 5% longer than the driven element, creating a phase lag that reflects energy forward. Conversely, directors are shorter, creating a phase lead that pulls the energy in the desired direction of propagation.

Mathematical Modeling of Element Length

The standard formula for calculating a half-wave dipole in free space is $L = 468 / f$ (where L is in feet and f is in MHz). However, Kent Britain's designs often account for the **Velocity Factor (VF)** of the materials used. Whether utilizing 1/8" aluminum rods, copper wire, or metallic foil, the physical diameter of the element affects its electrical length. A thicker element provides a wider **Q factor**, allowing for a broader bandwidth, which is critical for HDTV reception where multiple channels must be captured by a single array.

Analyzing the Cheap Yagi Architecture

The "Cheap Yagi" is perhaps the most famous contribution from WA5VJB to the hobbyist community. Its primary goal is to provide high-gain performance using materials available at any local hardware store. The design typically utilizes a non-conductive boom-often a simple wooden dowel-to eliminate the need for complex insulation between the elements and the boom.

Structural Mechanics and Material Selection

In Britain's methodology, the use of 1/8" diameter elements is standard for VHF and UHF versions. This choice is not arbitrary; it balances structural rigidity with electrical efficiency. When building for the 144 MHz (2-meter) or 440 MHz (70-centimeter) bands, the skin effect dictates that current flows primarily on the outer surface of the conductor. Therefore, solid rods or hollow tubes of these dimensions perform identically in terms of RF gain.

Antenna Type	Typical Gain (dBi)	Bandwidth Efficiency	Primary Application
Simple Dipole	2.15	High (Narrow)	General Purpose
Cheap Yagi (6-ele)	10.0 - 12.0	Moderate	Point-to-Point / Satellite
PCB Log Periodic	6.0 - 8.0	Extremely High (Wide)	Test Equip / Wideband RX
Foil Bowtie	3.5 - 5.0	High	HDTV Indoor Reception

The Role of the Driven Element

The driven element in a WA5VJB Cheap Yagi is usually a simple **J-shape** or a **folded dipole**. This is critical for impedance matching. A standard Yagi's inherent impedance can drop to 20-25 ohms as more directors are added. Since most coaxial cables (RG-58 or RG-6) are 50 or 75 ohms, a mismatch occurs. Britain's designs often solve this through specific spacing and the "Cheap" matching method, which avoids expensive gamma matches or baluns by utilizing the geometry of the driven element itself to achieve a near 1:1 Standing Wave Ratio (SWR).

PCB Log Periodic Antennas: Precision at High Frequencies

As we move into the microwave spectrum (400 MHz to 11 GHz), physical construction tolerances become much tighter. A deviation of 1mm at 10 GHz can completely shift the antenna's resonant frequency. This is where **PCB Log Periodic Antennas** become indispensable. Kent Britain has developed a wide array of these antennas printed directly on FR-4 or high-frequency laminates.

Log-Periodic Geometry

Unlike the Yagi, which is a narrowband antenna, the Log Periodic Dipole Array (LPDA) is frequency-independent over a wide range. The design follows a logarithmic ratio (τ) for the lengths and spacings of the elements. In a PCB implementation, the "elements" are traces of copper. The advantage of the PCB format is the ability to integrate **Microstrip Feedlines**. By controlling the trace width and the dielectric constant of the board, the feedline acts as an integrated impedance transformer.

Design Challenges in PCB LPs

- Dielectric Loss: Standard FR-4 material becomes "lossy" above 2-3 GHz. For Kent Britain's 11 GHz designs, specialized substrates or careful trace compensation are required.
- Phase Reversal: LPDAs require a 180-degree phase shift between adjacent elements. On a PCB, this is achieved by crisscrossing the feedlines or using both sides of the board.
- Precision Etching: The narrow tips of the higher-frequency elements must be etched with high precision to maintain gain at the top of the band.

Step-by-Step Field Guide: Building a 4-Element Cheap Yagi

Based on the technical documents provided by WA5VJB, this procedure outlines the construction of a UHF Yagi suitable for HDTV or amateur radio operations.

1. Boom Preparation

Select a 1/2" square wooden strip. Wood is used because it has a negligible effect on the

antenna's electrical properties (dielectric constant ~ 2.0). Mark the positions for the Reflector, Driven Element, and Directors based on the specific frequency chart provided in the *CheapYagi.pdf* documentation.

2. Element Fabrication

Cut four lengths of 1/8" aluminum rod or #12 AWG solid copper wire. Ensure the cuts are precise within 1/16th of an inch. For a 440 MHz antenna, the lengths would roughly follow this hierarchy:

1. Reflector: 13.5 inches
2. Driven Element: 13.0 inches (total length before bending/folding)
3. Director 1: 12.0 inches
4. Director 2: 11.5 inches

3. Element Mounting

Drill small holes through the wooden boom at the marked intervals. Press the elements through the holes. To secure them, a drop of epoxy or hot glue is sufficient. In the WA5VJB design, the elements are not grounded to each other; they remain isolated by the wood.

4. The Feed Point

The coax cable should be stripped, with the center conductor soldered to one side of the driven element and the shield to the other. For weatherproofing in outdoor installations, the feed point must be encased in a UV-resistant sealant or a small plastic enclosure.

The Foil Antenna Project: High-Performance HDTV on a Budget

One of the more innovative adaptations of Britain's work is the conversion of these designs into **Foil Antennas**. This approach is particularly effective for indoor HDTV reception. By using heavy-duty aluminum foil or copper tape on a cardboard or poster board backing, users can create a high-gain antenna that is virtually weightless.

Skin Effect and Surface Area

Because RF energy travels on the surface, the thinness of the foil does not hinder performance. In fact, the wide surface area of a foil "bowtie" or "element" can actually improve bandwidth. This is why foil antennas often outperform commercial "thin" antennas; they are built on better geometric principles found in Britain's references.

Technical Comparison: Materials and Performance

The choice of material significantly impacts the durability and the **Velocity Factor** of the antenna.

The following table compares common materials used in DIY WA5VJB designs.

Material	Conductivity	Durability	Best Use Case
Copper Wire (#12)	Excellent	Moderate	Fixed Indoor/Attic Installations
Aluminum Rod (1/8")	Good	High	Portable/Outdoor Yagis
Aluminum Foil	Good	Low	Experimental/Temporary HDTV
PCB (Copper Trace)	Excellent	Very High	Microwave/High-Frequency Arrays

Troubleshooting and Performance Optimization

Even the best design can fail if environmental factors are ignored. Here are the most common failure modes in DIY antenna construction and their engineering solutions:

1. Multipath Distortion

In urban environments, signals bounce off buildings, arriving at the antenna at different times. This causes "ghosting" in analog or "pixelation" in digital signals. **Solution:** Increase the **Front-to-Back (F/B) Ratio** of your Yagi. By adding more directors, you narrow the beamwidth, allowing the antenna to "ignore" signals coming from off-axis angles.

2. Impedance Mismatch (High SWR)

If your transmitter gets hot or your receiver gets no signal, your SWR might be too high. **Solution:** Re-examine the feed point. Ensure the coax is not pinched or damaged. In Britain's designs, the distance between the Reflector and the Driven Element is the most sensitive parameter for impedance. Small adjustments (moving the reflector 1/4" closer or further) can dramatically improve the match.

3. Polarization Mismatch

Antennas must be oriented in the same plane as the transmitting tower. Most TV signals and amateur repeaters use **Vertical Polarization**, while some specialized long-distance SSB communication uses **Horizontal Polarization**. **Solution:** Rotate the boom 90 degrees. If the elements are pointing up and down, you are vertically polarized. If they are side-to-side, you are horizontal.

The Broader Implications of Accessible RF Design

The work of Kent Britain WA5VJB proves that high-performance RF engineering does not require a multi-million dollar laboratory. By adhering to the fundamental laws of physics—specifically Maxwell's equations and the principles of parasitic resonance—individuals can construct communication tools that rival commercial products. The "Cheap Yagi" is more than just a project; it is a testament to the efficiency of minimal design. Whether it is a PCB Log Periodic operating at 10 GHz or a foil-based HDTV antenna in a living room, these designs prioritize electrical truth over aesthetic complexity. As we move further into a world dominated by wireless connectivity, the ability to understand and build one's own aperture to the electromagnetic spectrum remains a vital and empowering skill for engineers and hobbyists alike.