AMATEUR RADIO TECHNOLOGY

The Engineering of Shortened Multiband End-Fed Half Wave (EFHW) Antennas: A Technical Guide for 80m-10m Operation

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In the realm of amateur radio, the **End-Fed Half Wave (EFHW)** antenna has emerged as a preferred solution for operators seeking multiband capability with minimal physical footprint. Unlike the traditional center-fed dipole, which requires a balanced feedline and central support, the EFHW is fed at a high-impedance voltage point at one end. This configuration is particularly advantageous for portable operations (POTA/SOTA) and space-constrained residential installations. However, a standard EFHW for the 80-meter band requires approximately 40 meters of wire—a length that remains prohibitive for many. The development of the **shortened multiband EFHW**, specifically the 23-meter variant popularized by designers like Steve Nichols (G0KYA), represents a significant engineering compromise that balances physical size against electromagnetic efficiency.

The Theoretical Framework of EFHW Antennas

To understand the shortened EFHW, one must first grasp the physics of a standard half-wave radiator. A wire cut to a half-wavelength at a fundamental frequency (f) will also be resonant at integer multiples of that frequency (2f, 3f, 4f, etc.). This harmonic relationship allows a single wire to operate across multiple amateur bands without the need for complex traps or stubs. For example, a wire resonant on 40m (7 MHz) will naturally show resonance near 20m (14 MHz), 15m (21 MHz), and 10m (28 MHz).

The primary challenge of the EFHW is its **feedpoint impedance**. While a center-fed dipole presents an impedance of approximately 72 ohms, an end-fed half-wave wire presents a high impedance, typically ranging from 1,800 to 4,000 ohms. To interface this with standard 50-ohm coaxial cable, a specialized impedance-matching transformer, known as a **9:1 or 49:1 UnUn (Unbalanced-to-Unbalanced)**, is required. In most multiband EFHW applications, a 49:1 transformer is utilized to step down the high voltage/low current at the end of the wire to the low voltage/high current required by the transceiver.

The 80-Meter Challenge and Inductive Loading

The 80-meter band (3.5–4.0 MHz) presents a physical hurdle: a full half-wave is roughly 40 meters (131 feet). In many suburban environments, a 40-meter run is impossible. The engineering solution is **inductive loading**. By inserting a high-Q loading coil at a specific point along the radiator, the antenna can be electrically lengthened while remaining physically short. In the G0KYA design, a coil is placed near the far end of a 23-meter wire. This placement allows the antenna to function as a full half-wave on 40 meters (where the coil acts as a minor inductor) while providing the necessary phase shift to achieve resonance on 80 meters within a significantly reduced physical span.

Technical Analysis: The 23-Meter Multiband Design

The shortened EFHW described in technical literature typically utilizes a 22-23 meter radiator. This length is intentional; it is slightly longer than a half-wave for 40 meters, allowing the designer to use the excess length and a loading coil to find resonance on the lower 80-meter band. The following table illustrates the typical performance metrics of a shortened EFHW versus a full-sized resonant dipole.

Metric	Shortened EFHW (23m)	Full-Size Dipole (80m)	Full-Size EFHW (40m)
Physical Length	~23 Meters	~40 Meters	~40 Meters
80m Bandwidth (SWR < 3:1)	~300 kHz	~250-500 kHz	N/A
Efficiency on 80m	-8dB to -12dB vs Dipole	Reference (0dB)	N/A
Multiband Native Support	80, 40, 20, 15, 10m	Single Band (usually)	40, 20, 15, 10m
Feedpoint	End (High Z)	Center (Low Z)	End (High Z)

Loading Coil Mechanics and Placement

The placement of the loading coil is critical. If the coil is placed too close to the feedpoint, it restricts the bandwidth significantly and increases losses. In the 80/40/20/10m shortened EFHW, the coil is often placed after the first 20 meters of wire. This ensures that for the 40m, 20m, and 10m bands, the antenna behaves largely as a standard radiator. The final few meters of wire after the coil are adjusted specifically to bring the 80m resonance into the desired portion of the band (e.g., 3.65 MHz for digital/CW or 3.75 MHz for phone).

Formula for Inductive Reactance: *XL = 2< dÀ*To "trick" the radio into seeing a 40-meter wire on an 80-meter frequency, the coil must provide enough reactance to compensate for the missing ~17 meters of wire. However, this comes at the cost of **Radiation Resistance (Rr)**. As the antenna is shortened, Rr drops, and ohmic losses in the coil and ground become a larger percentage of the total impedance, leading to the observed 8-12dB drop in performance compared to a full-sized dipole.

The Broadband Matching Network (The 49:1 UnUn)

The heart of the EFHW system is the transformer. To cover 3.5 MHz to 30 MHz, a broadband toroidal transformer is required. Typically, an **FT240-43 ferrite core**is used for power levels up to 100-200 watts. The transformer usually consists of 2 primary turns and 14 secondary turns (a 1:7 turns ratio). Since the impedance transformation is the square of the turns ratio ($7^2 = 49$), this creates the necessary 49:1 ratio.

Core Saturation and Heat Dissipation

A common failure mode in shortened EFHW antennas is **magnetic core saturation**. Because the antenna is shortened and uses a loading coil, the SWR on some bands (like 20m or 15m) may be higher than 2:1. Operating at high power (FT8 or CW) can cause the ferrite core to heat up. As the core reaches its **Curie temperature**, its magnetic properties degrade, SWR rises rapidly, and the core can be permanently damaged. For high-power applications, designers often stack two or three FT240-43 cores to distribute the magnetic flux.

Step-by-Step Practical Implementation Guide

Building or installing a shortened multiband EFHW requires precision. Follow these engineering steps for optimal deployment:

1. Transformer Assembly: Wind the 49:1 UnUn using high-quality enameled copper wire. Ensure the primary and secondary windings are tight against the core to minimize leakage inductance.
2. Radiator Preparation: Cut approximately 20.2 meters of UV-resistant antenna wire (like Poly-Stealth). This

will be your primary radiator for 40m-10m.

3. Loading Coil Construction: Use a PVC form (approx. 25-40mm diameter). Wind enough turns to achieve approximately 80-110 ;Ä, öb –æGV7F æ6P. The exact value depends on the final wire length after the coil.
4. The "Tail": Attach a further 2-3 meters of wire after the loading coil. This is the adjustment tail for the 80m band.
5. Initial Testing: Suspend the antenna at its intended operating height. An inverted sloper (apex at 8m-10m) is a common configuration.
6. Tuning Sequence: Always tune from the highest frequency down. Adjust the 40m length first by trimming the 20.2m section. Once 40m is resonant, adjust the 80m resonance by trimming the tail wire after the coil.

Environmental Impacts on Performance

The EFHW is sensitive to its surroundings. Proximity to structures, the height above ground, and soil conductivity significantly alter the feedpoint impedance. For example, if the antenna is mounted too low (less than 5 meters), the capacitance to ground will lower the resonant frequency and potentially increase the SWR across all bands. Additionally, while the EFHW is marketed as "no counterpoise needed," the physics of the antenna requires a return path for current. This is typically provided by the **coaxial shield**. To prevent Common Mode Current (CMC) from entering the shack and causing RFI, a 1:1 current balun (choke) should be placed approximately 0.05;° to 0.1;° away from the UnUn transformer.

MMANA-GAL Modeling and Simulation Insights

Technical modeling using **MMANA-GAL**or EZNEC reveals the trade-offs of the shortened design. Simulation shows that while the 40m and 20m radiation patterns remain largely similar to a standard dipole (broadside lobes), the 10m pattern becomes highly multi-lobed. On 80m, the radiation pattern is nearly omnidirectional but heavily influenced by ground losses due to the shortened physical length.

SWR Performance Matrix (Typical Results)

Band	Center Frequency	Expected SWR	Note
80m	3.650 MHz	1.3:1 - 1.5:1	Narrow bandwidth (~100-300kHz)
40m	7.100 MHz	1.2:1	Full half-wave resonance
20m	14.150 MHz	1.8:1 - 2.5:1	Requires ATU in some sections
15m	21.200 MHz	2.0:1 - 2.8:1	Harmonic resonance (3rd)
10m	28.400 MHz	1.5:1 - 2.5:1	Harmonic resonance (4th)

Troubleshooting and Optimization Strategies

Operators frequently encounter challenges during the deployment of shortened EFHW antennas. The most common issue is a high SWR on all bands. This is often indicative of a failure in the UnUn transformer or an inadequate return path. If SWR is high only on 80m, the loading coil is likely the culprit—either the inductance is incorrect, or the "tail" wire is interacting with nearby metal objects.

Common Failure Modes and Solutions

- Problem: RF in the Shack. This occurs when the coax shield acts as the counterpoise and radiates inside the building. Solution: Install a high-quality ferrite choke (1:1 Balun) on the coax at least 3-5 meters away from the antenna feedpoint.
- Problem: High SWR on high bands (10m/15m). Often caused by excessive lead lengths inside the UnUn enclosure. Solution: Keep all internal transformer connections as short as possible. Use a small 100-150pF high-voltage capacitor across the primary of the 49:1 transformer to compensate for leakage inductance.
- Problem: Narrow 80m Bandwidth. A natural consequence of shortening. Solution: If you need to cover both CW and SSB portions of 80m, an external Antenna Tuner (ATU) will be necessary, or you must choose a specific segment of the band to optimize for.

Comparative Analysis: EFHW vs. Other Compact Antennas

When compared to **Magnetic Loops** or **Verticals**, the shortened EFHW offers a unique set of advantages. Magnetic loops are even more compact but suffer from extremely narrow bandwidth and high voltage across the capacitor. Verticals require an extensive radial system to be effective, which can be more labor-intensive than hanging a single wire. The shortened EFHW (23m) remains the "middle ground" for the ham who wants 80m access without the footprint of a full dipole or the complexity of a vertical ground plane.

The 8-12dB loss on 80m, while significant on paper, is often manageable. In practical terms, a station that is S9+20dB with a full-sized dipole might be S9 or S9+5dB with the shortened EFHW. For the majority of contacts, this difference does not prevent a successful QSO. It is a small price to pay for the ability to operate on the 80m band from a small backyard.

The evolution of the shortened multiband EFHW antenna demonstrates the power of inductive loading and transformer impedance matching in modern antenna design. By reducing the 80m radiator to 23 meters, engineers have enabled thousands of amateur radio operators to participate in low-band DXing and emergency communications. While the physics dictates certain compromises in efficiency and bandwidth, the practical utility of a single-wire, multiband solution is undeniable. As ferrite technology improves and modeling software becomes more accessible, we can expect further refinements in loading coil efficiency and transformer broadbanding, ensuring the EFHW remains a cornerstone of the amateur radio station for years to come.

Tags: #EFHW #80m Antenna #Multiband Antenna #Antenna Engineering #G0KYA #UnUn Transformer