Patent Comparison Report

Field Coil Metal Detector (FCMD) vs. US Patent 7579839B2

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Project: FCMD (Field Coil Metal Detector)
Patent: US7579839B2 - Metal Detector (Minelab Electronics Pty Ltd)
Patent Status: Active until June 29, 2026 (Expires in ~7 months)

Executive Summary

This report provides a comprehensive technical comparison between the FCMD (Field Coil Metal Detector) Android application and Minelab's US Patent 7579839B2 for a multi-frequency metal detector. Both systems employ multi-frequency electromagnetic detection with synchronous demodulation, but differ fundamentally in their transmit waveform approach and implementation platform.

> **Key Finding:** FCMD uses **multi-tone sine wave transmission**, while the patent specifically claims **switched rectangular voltage waveforms**. This represents a fundamental architectural difference that significantly reduces patent infringement risk.

> **Legal Disclaimer:** This is a technical comparison only. For definitive legal guidance regarding patent infringement, consult a qualified patent attorney specializing in electronics and digital signal processing.

1. Patent US7579839B2 Overview

Attribute	Details
Title	Metal Detector
Assignee	Minelab Electronics Pty Ltd
Issue Date	August 25, 2009
Expiration Date	June 29, 2026 (~7 months remaining)
Status	Active

1.1 Core Innovation

The patent describes a real-time electronic metal detector that uses **approximate sine-wave weighted synchronous demodulation** with a **switched voltage signal**. The key innovation is the use of multi-period rectangular waveforms that are "Fourier-rich" (containing multiple harmonic frequencies) combined with digital signal processing for demodulation.

1.2 Problem Addressed

- High cost of multi-frequency analogue electronics in traditional detectors
- Poor electromagnetic interference rejection in time-domain detectors
- Limited simultaneous frequency detection capabilities
- Lack of user-selectable frequency adjustment in practical systems

1.3 Technical Approach

- **Switched voltage signal generation:** Multi-period rectangular waveform applied to magnetic transmitter coil

- **Digital signal processing:** Real-time synchronous demodulation using approximate sine/cosine weighting functions
- **Operator-selectable frequencies:** Users can adjust detection frequencies via controller switches
- **Fourier-rich waveforms:** Transmit signals mathematically designed to be rich in desired frequencies

1.4 Specific Technologies

Parameter	Specification
Example Frequencies	1 kHz (conductive objects), 2 kHz (coins), 16 kHz (small gold nuggets)
Sampling Rate	96,000 Hz (1/96,000 second intervals)
Detection Method	Fundamental, third, and higher harmonics via Fourier analysis
Waveform Type	Switched voltage / Rectangular waveform

2. FCMD Project Overview

2.1 Project Description

FCMD (Field Coil Metal Detector) is a professional-grade Android metal detector application that transforms a smartphone into a sophisticated electromagnetic metal detection system. The project leverages the device's audio hardware for signal generation and processing, enabling metal detection capabilities previously only available in dedicated commercial hardware.

2.2 Core Technology

Component	Implementation
Platform	Android 5.0+ (Kotlin 1.9)
Signal Generation	Multi-tone sinusoidal (1-24 tones, logarithmically spaced)
Frequency Range	1 kHz - 20 kHz
Sample Rate	44,100 Hz
Demodulation	IQ (In-phase/Quadrature) with single-pole IIR filtering (α=0.002)
Processing	Real-time DSP pipeline (~23 Hz callback rate)
Hardware	External TX/RX coils connected to phone audio jack

2.3 Key Features

Feature	Description
Multi-Frequency Detection	1-24 tones, logarithmically spaced from 1-20 kHz
VDI Classification	0-99 scale: Ferrous (0-30), Non-ferrous conductors (30-99)
Target Type Classification	Ferrous, Low/Mid/High Conductors, Gold Range, Unknown
Ground Balance	4 modes: OFF, Manual, Auto-Tracking, Manual+Tracking
Depth Estimation	5 categories (Surface to Very Deep) with confidence scoring
Coherent Demodulation	TX reference signal for automatic clock drift cancellation
Audio Feedback	Pentatonic scale (261-1760 Hz) mapped to VDI values
Bluetooth Support	Automatic routing to Bluetooth headsets/speakers

2.4 Technical Architecture

The FCMD system comprises 18 Kotlin source files totaling approximately 5,225 lines of code. Key components include:

- `AudioEngine.kt` - Audio I/O management (398 lines)
- `IQDemodulator.kt` - IQ demodulation core (369 lines)
- `VDICalculator.kt` - Target discrimination algorithm (252 lines)
- `GroundBalanceManager.kt` - Ground balance implementation (313 lines)
- `DepthEstimator.kt` - Depth estimation with calibration (208 lines)
- `MultiToneGenerator.kt` - TX signal generation (119 lines)

- `AudioToneGenerator.kt` - Audio feedback synthesis (335 lines)
- `BluetoothAudioManager.kt` - Bluetooth audio routing (303 lines)

3. Technical Comparison

3.1 Similarities (Conceptual Overlap)

Aspect	Patent US7579839B2	FCMD
Multi-frequency detection	**✓ Yes (1, 2, 16 kHz examples)**	**✓ Yes (1-24 tones, 1-20 kHz)**
Synchronous demodulation	**✓ Sine/cosine weighting**	**✓ IQ demodulation (I=cos, Q=sin)**
Digital signal processing	**✓ Real-time DSP**	**✓ Real-time DSP (Kotlin/Android)**
Operator-selectable frequencies	**✓ Via controller switches**	**✓ Via UI (1-24 tones, adjustable max)**
Low-cost implementation	**✓ Digital switching vs analog**	**✓ Smartphone audio hardware**
Phase & amplitude extraction	**✓ Yes**	**✓ Yes (IQ components)**

3.2 Critical Differences

3.2.1 Transmit Signal Type KEY DIFFERENTIATOR

Patent US7579839B2: "Switched voltage signal" — multi-period **rectangular waveform** rich in harmonics

FCMD: Multi-tone sine waves — sum of pure sinusoids generated digitally

Significance: The patent specifically claims the use of switched/rectangular waveforms. FCMD uses additive sine wave synthesis, which is fundamentally different in both generation method and spectral characteristics.

Waveform Comparison

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Patent Approach (Fourier-rich rectangular):
     +V ┌───┐     ┌───┐
        │   │     │   │
    0V ─┘   └─────┘   └───
        Rich in harmonics (1f, 3f, 5f, 7f...)

FCMD Approach (Multi-tone sinusoidal):
        Σ A_i * sin(2πf_i*t), i=1 to 24

        Superposition of discrete frequencies
        Precise control over which frequencies are present
```

3.2.2 Hardware Platform

Aspect	Patent	FCMD
Platform	Dedicated metal detector hardware	Android smartphone + external coils
Signal Generation	Custom digital switching circuitry	Phone audio codec (DAC)
Signal Reception	Dedicated receiver circuit	Phone microphone input (ADC)

3.2.3 Sampling Rate

System	Sample Rate	Nyquist Frequency
Patent US7579839B2	96,000 Hz	48 kHz
FCMD	44,100 Hz	22.05 kHz (constrains max frequency to 20 kHz)

3.2.4 Feature Complexity

Patent Focus: Core multi-frequency detection mechanism with synchronous demodulation

FCMD Additional Features (not mentioned in patent):

- VDI (Visual Discrimination Index) classification system
- Phase slope analysis for metal type identification (deg/kHz)
- Ground balance with 4 modes including auto-tracking
- Depth estimation with confidence scoring
- **Coherent demodulation** using TX reference signal (clock drift cancellation)
- Bluetooth audio routing
- Conductivity index calculation
- Real-time waveform visualization
- Pentatonic audio feedback system

3.2.5 Demodulation Implementation

System	Method	Details
Patent	"Approximate" sine-wave weighting	Suggests lookup tables or simplified mathematical operations
FCMD	Precise IQ demodulation	Single-pole IIR filtering (α=0.002, cutoff ~14 Hz)

4. Patent Infringement Risk Assessment

4.1 Low Risk Indicators

1. Different Transmit Signal Type LOW RISK

Patent Claim: Rectangular switched voltage waveforms
FCMD Implementation: Multi-tone sinusoidal waveforms
Assessment: This is a fundamental architectural difference. The patent specifically describes and claims rectangular waveforms that are "Fourier-rich" in harmonics. FCMD's approach of digitally synthesizing discrete sine tones is conceptually and mathematically distinct.

2. Patent Expiration Imminent LOW RISK

Expiration Date: June 29, 2026 (less than 7 months remaining)
Assessment: Even if there were infringement concerns, the patent will enter the public domain soon, allowing unrestricted use of the claimed invention.

3. Different Application Domain LOW RISK

Patent Context: Dedicated hardware metal detector
FCMD Context: Smartphone software application
Assessment: While this doesn't eliminate infringement risk (patents can cover methods regardless of implementation), the substantial differences in platform and implementation reduce overlap.

4. Synchronous Demodulation is Not Novel LOW RISK

Context: IQ demodulation is a fundamental DSP technique
Assessment: Synchronous demodulation predates this patent and is used extensively in radio, radar, sonar, and telecommunications. The patent's claims are likely limited to the specific combination with switched rectangular waveforms, not the demodulation technique itself.

4.2 Potential Overlap Areas

Areas of Conceptual Similarity MEDIUM CONCERN

1. **Multi-frequency simultaneous detection:** Both systems detect multiple frequencies concurrently
2. **Synchronous demodulation:** Both use phase-coherent mixing (though with different waveforms)
3. **Operator frequency selection:** Both allow user-selectable frequency configurations

Assessment: These similarities exist at a high conceptual level but differ in implementation details. Multi-frequency detection and synchronous demodulation are well-established techniques in signal processing. The key question is whether the patent's claims are broad enough to cover any multi-frequency metal detector using synchronous demodulation, or narrowly limited to the specific switched rectangular waveform approach.

4.3 FCMD's Unique Contributions

Features implemented in FCMD that are **not described in Patent US7579839B2:**

- **Coherent demodulation with TX reference:** Automatic clock drift compensation between phone and USB audio dongles
- **VDI classification algorithm:** Phase slope-based metal discrimination (degrees/kHz)
- **Conductivity index calculation:** High/low frequency amplitude ratio analysis
- **Categorical depth estimation:** Five-level depth classification with confidence scoring
- **Smartphone-based implementation:** Novel use of mobile audio codec for metal detection
- **Logarithmic frequency spacing:** Optimized frequency distribution for target discrimination
- **Ground balance auto-tracking:** Adaptive baseline compensation with freeze-on-target

- **Bluetooth audio routing:** Wireless headset integration
- **Real-time performance monitoring:** CPU usage, latency, and buffer statistics

4.4 Overall Risk Assessment

Risk Level: LOW LOW RISK

Based on this technical analysis, the patent infringement risk appears **LOW** due to:

- Fundamental difference in transmit waveform type (sine vs. rectangular)
- Imminent patent expiration (June 2026)
- Different implementation platform and approach
- Significant additional innovations not covered by the patent

However, **this is not legal advice**. For definitive guidance, consult a patent attorney who can:

1. Analyze the full claims language of US7579839B2
2. Review Minelab's patent portfolio for related patents with broader claims
3. Assess whether the claims cover the method regardless of waveform type
4. Evaluate doctrine of equivalents considerations
5. Provide jurisdiction-specific legal guidance

5. Detailed Technical Distinctions

5.1 Signal Generation Comparison

Characteristic	Patent US7579839B2	FCMD
Waveform Shape	Rectangular (square wave variants)	Sinusoidal (pure tones)
Generation Method	Voltage switching circuit	Digital synthesis (DAC)
Harmonic Content	Natural harmonics from square wave (1f, 3f, 5f, 7f...)	Only explicitly programmed frequencies
Frequency Control	Switching timing determines harmonic structure	Direct frequency synthesis for each tone
Spectral Purity	Broad spectrum with many harmonics	Discrete tones at specific frequencies

5.2 FCMD's IQ Demodulation Algorithm

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For each frequency f:
1. Phase increment: φ_inc = 2π × f / sample_rate

2. For each audio sample x[n]:
   - I[n] = x[n] × cos(φ)   // In-phase component
   - Q[n] = -x[n] × sin(φ) // Quadrature component
   - φ = φ + φ_inc

3. Single-Pole IIR Low-Pass Filter (α=0.002):
   - I_filtered = 0.002 × I + 0.998 × I_filtered
   - Q_filtered = 0.002 × Q + 0.998 × Q_filtered
   - Cutoff ≈ 14 Hz (very stable, integrates noise)

4. Output per buffer (~43 ms):
   - Amplitude = √(I² + Q²) × 2.0  // ×2 for mixing loss compensatic
   - Phase = atan2(Q, I)
```

5.3 FCMD's Phase Slope Discrimination

This is a unique feature not mentioned in the patent:

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Phase Slope = (phase_high - phase_low) / (frequency_high - frequency

Interpretation:
- Ferrous metals: slope < -3.0 deg/kHz (strong negative slope)
  → VDI = 30 × (1.0 - slope / -10.0)  // Maps to 0-30 range

- Non-ferrous: flat slope, use conductivity index
  → VDI = 30 + conductivity × 69  // Maps to 30-99 range

Conductivity Index:
- Ratio = amplitude(high freq) / amplitude(low freq)
- Normalized = clamp(ratio, 0.0, 2.0) / 2.0
- High conductors (Cu, Ag): ratio > 1.0
- Low conductors (Al, foil): ratio < 1.0
```

5.4 FCMD's Coherent Demodulation

A recent innovation addressing clock drift between phone and USB audio dongles:

- **Problem:** Phone DAC and external USB ADC may have slightly different clock rates
- **Solution:** Loop TX signal back to right channel of microphone input
- **Method:** Demodulate both RX signal and TX reference, compute relative phase
- **Benefit:** Automatic cancellation of clock drift errors, improved phase stability

5.5 Ground Balance Implementation

Mode	Description	Algorithm
OFF	No ground balance applied	Use raw RX signal
Manual	User "pumps" coil 10 times	Average 10 samples, store as baseline, subtract from future readings
Auto-Tracking	Continuously adapts to soil	Slow IIR filter (α=0.0005); freezes when target detected (amplitude > 0.3)
Manual+Tracking	Start from manual, then track	Use manual baseline as starting point, then apply auto-tracking

User Offset: ±50 adjustment range for fine-tuning the null point

6. Conclusions and Recommendations

6.1 Summary of Findings

This technical comparison reveals that while FCMD and Patent US7579839B2 share the high-level concept of multi-frequency synchronous demodulation for metal detection, they differ fundamentally in their implementation approach:

Aspect	Similarity Level	Notes
Transmit waveform	✗ **Different**	Rectangular (patent) vs. Sinusoidal (FCMD)
Hardware platform	✗ **Different**	Dedicated detector vs. Smartphone
Multi-frequency concept	✓ **Similar**	Both use multiple simultaneous frequencies
Synchronous demodulation	✓ **Similar**	Standard DSP technique, implementation differs
Feature set	✗ **Different**	FCMD has many additional unique features

6.2 Patent Infringement Risk

Overall Assessment: LOW RISK LOW RISK

Primary Risk Mitigation Factors:

- **Waveform difference:** Sine waves vs. rectangular is a fundamental distinction
- **Expiration timeline:** Patent expires June 29, 2026 (~7 months)
- **Standard techniques:** Synchronous demodulation is well-established prior art
- **Platform distinction:** Smartphone implementation vs. dedicated hardware

6.3 Recommendations

1. Legal Consultation

Engage a patent attorney specializing in electronics/DSP to:

- Review the full claims language of US7579839B2
- Conduct a freedom-to-operate (FTO) analysis
- Search for related Minelab patents with potentially broader claims
- Assess international patent implications if distributing globally

2. Patent Expiration Strategy

Given the patent expires in ~7 months (June 2026):

- Consider timing of commercial launch relative to expiration date
- Monitor for any patent term extensions or continuations
- After expiration, all claims enter public domain

3. Documentation

Maintain clear documentation of FCMD's unique innovations:

- Coherent demodulation with TX reference
- VDI phase slope algorithm
- Smartphone-based architecture
- Multi-tone sinusoidal synthesis approach

This demonstrates independent development and novel contributions to the field.

4. Prior Art Research

Investigate prior art for multi-frequency metal detection and synchronous demodulation:

- Academic papers on metal detection algorithms
- Earlier patents in the metal detection field
- Radio/radar/sonar DSP techniques (IQ demodulation origins)

This can help establish that core techniques predate the Minelab patent.

6.4 Final Statement

Technical Conclusion

FCMD represents a novel implementation of multi-frequency metal detection using smartphone audio hardware and multi-tone sinusoidal transmission. While it shares conceptual similarities with Patent US7579839B2 in using multi-frequency detection and synchronous demodulation (both well-established techniques in signal processing), it differs fundamentally in:

- Transmit waveform type (sine vs. rectangular)
- Implementation platform (smartphone vs. dedicated hardware)
- Feature set (VDI, phase slope analysis, coherent demodulation, etc.)

These differences, combined with the patent's imminent expiration, suggest low infringement risk. However, **this technical analysis does not constitute legal advice**. Consultation with a qualified patent attorney is strongly recommended for authoritative legal guidance.

Report Generated: November 11, 2025

Project: FCMD (Field Coil Metal Detector)

Disclaimer: This report is for informational purposes only and does not constitute legal advice.