

# MATLAB SAW Filter Analysis Toolbox (SAWFAT)

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The SAW Filter Analysis Toolbox (SAWFAT) is a collection of MATLAB software tools for the analysis of in-line or dual-track IF SAW filters. The author develops and maintains a comprehensive SAWFAT theoretical background and user manual. The documentation covers installation instructions, software capabilities, GUI and data format descriptions, and tutorial SAW filter analysis examples. Moreover, SAWFAT provides tools for automatic SAW filter photomask generation in [AutoCAD \(Autodesk®\)](#) DXF format, which most photomask writers accept.

This page describes and links to two key technical documents: a detailed SAWFAT theoretical background and a practical [MATLAB® \(Mathworks\)](#) SAWFAT User Manual.

## 1. SAW Filter Analysis in the Quasi-Static Approximation: Theory and Algorithms

This document introduces a progressive learning path for SAW filter modeling in the quasi-static approximation. It starts with fundamentals of periodic SAW transducers and then advances toward SAW filter modeling and MATLAB software development.

### ***Modeling Assumptions***

By default, bidirectional periodic SAW interdigital transducers (IDTs) operate as non-reflective elements in the quasi-static approximation. However, SAWFAT 1.2 and higher also supports bidirectional SAW filters with reflective periodic unapodized or apodized IDTs. The author applies an undocumented semi-heuristic reflective model in this case. This extension improves SAW filter simulation accuracy in some applications. In particular, the model correctly accounts for reflections at IDT ends, even when interelectrode reflections are weak, such as in split-finger IDTs.

### **SAW Filter Construction**

SAWFAT analyzes SAW filters that consist of two cascaded IDTs:

- 1) In-line structure: input unapodized (regular or polarity-weighted) IDT and output unapodized or apodized (aperture-weighted) IDT
- 2) Dual-track structure: input and output apodized IDTs, identical or different, coupled via an MSC.

### **SAW Transducer Configuration**

SAW transducers may be unapodized with uniform aperture, polarity-weighted, or apodized (aperture-weighted). However, the theory applies only to periodic IDTs with constant period and metallization ratio. The quasi-static approximation applies when the central frequency  $f_0$  is sufficiently far from the synchronous frequency  $f_s = v / 2p$ , where  $v$  is the SAW velocity and  $p$  is the IDT period. For split-finger IDTs used in IF SAW filters,  $f_s$  equals  $2f_0$ . No additional restrictions on the ratio  $f_s/f_0$  apply.

### **MSC Modeling**

SAWFAT uses a modal expansion of acoustic waves in a periodic MSC structure into two orthogonal modes: symmetric and antisymmetric ones. These modes correspond to those in open- and short-circuit periodic gratings, respectively. This model provides sufficient accuracy for most practical cases.

Based on this two-mode expansion, SAWFAT computes a  $4 \times 4$  dual-track scattering matrix. For each mode, SAWFAT allows the user to select one of the following periodic grating models:

- 1) Coupling-of-modes (COM)
- 2) Reflective array model (RAM)
- 3) Ingebrigtsen's closed-form field model
- 4) Morgan's quasi-static approximation

### **Mixed Scattering Matrix (P-Matrix) Calculation**

The mixed scattering matrix formalism plays a key role in SAWFAT modeling. SAWFAT derives matrix properties for lossless IDTs using reciprocity and

power conservation. It computes all independent terms of the  $3 \times 3$  mixed scattering matrices for arbitrary periodic SAW transducers. These include acoustoelectric/electroacoustic conversion functions and transducer admittance, including radiation conductance, susceptance, and static capacitance. For reflective IDTs, the mixed scattering matrix extends the quasi-static model by introducing a non-zero reflection coefficient, while the transmission coefficient is reduced from unity due to power conservation.

Each IDT uses tap weights proportional to finger overlaps. A proprietary algorithm computes responses using weighted sums of closed-form elemental admittances and capacitances. In this formulation, unapodized SAW transducers represent a special case of apodized transducers without aperture weighting.

### ***Quasi-Static Approximation***

In the quasi-static approximation, SAWFAT assumes negligible reflection from short-circuit transducers. However, SAWFAT 1.2 and higher also models reflection and conversion effects using a semi-heuristic reflective IDT model. For arbitrary metallization ratios, the toolbox evaluates both baseband and harmonic responses.

### ***SAW Filter Analysis***

In SAW filters, input and output IDTs couple either directly (in-line) or through an MSC (dual-track). SAWFAT cascades mixed scattering matrices to compute the overall filter response. As a result, the filter forms a reciprocal lossless two-port network described by either a  $2 \times 2$  admittance matrix (Y-matrix) or a scattering matrix (S-matrix).

SAWFAT computes both Y- and S-parameters and displays them in Cartesian or polar (Smith chart) coordinates. Furthermore, in the quasi-static approximation, the Y-matrix can be derived in closed form, which simplifies modeling.

### ***SAWFAT Output Results***

Finally, SAWFAT exports Y- and S-parameter matrices in TouchStone format compatible with commercial circuit simulators such as [Keysight® PathWave Advanced Design System \(ADS\)](#) . Moreover, S-parameters can be directly compared with network analyzer measurements.

## 2. SAWFAT MATLAB User Manual

### ***SAWFAT Structure and Organization***

The SAWFAT user manual describes the software structure, purpose, syntax, and usage of MATLAB and C/Fortran subroutines. It also presents GUI structure and core functions.

In addition, the manual includes tutorial examples and test results. Users can adapt sample data files to their own SAW filter designs. The manual also explains software execution and presents results in graphical form.

### ***SAWFAT MEX Files and Portability***

The author implements core SAWFAT functions as C or Fortran MATLAB MEX-files. The package includes full source code and gateway routines. Because the code is open source, users can select the most appropriate programming language and compiler. This improves flexibility, maintainability, and long-term usability of the software. Moreover, users can revise and recompile the code whenever MATLAB upgrades require it.

### ***SAWFAT Open Source Code***

Unlike many proprietary MATLAB toolboxes, SAWFAT is provided as open-source software on an as-is basis. Therefore, users can integrate SAWFAT into their own MATLAB workflows when needed. In addition, code inspection helps users understand the modeling algorithms and supports learning in SAW device design.

### ***SAWFAT MATLAB Integration and Extensibility***

The toolbox includes utilities for automated MEX-file generation. As a result, SAWFAT remains flexible and extendable, since users can adapt it to specific applications. The toolbox operates either as a standalone MATLAB package or as part of a larger SAW design workflow.

### ***Learning Objectives and Target Audience***

The package targets engineers, researchers, and students working with SAW devices. It supports both beginners and experienced SAW designers.

No prior SAW filter experience is required, since the documentation includes both theory and implementation details. Moreover, the package includes tutorial examples that demonstrate key features.

**Click one of the links below to download the material in PDF format:**

1. [\*\*SAW Filter Analysis in the Quasi-Static Approximation: Theory and Algorithms\*\*](#)
2. [\*\*SAW Filter Analysis Toolbox \(SAWFAT\): MATLAB User Manual\*\*](#)

Web version: [\*\*MATLAB SAW Filter Analysis Toolbox \(SAWFAT\)\*\*](#)