Automated Process Cuts Filter Tuning Time From Hours To Minutes

Fast, efficient tuning of S-, C-, and X-band filters reduces production time and cost for Army missile systems.

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At radio frequencies in the range of S-, C-, and X-band (2.6 to 12.4 GHz), manual tuning of lumped inductive-capacitive (LC) filters is cumbersome and time-consuming at best. But an Army Manufacturing Technology (ManTech) program has developed an automated process for tuning these filters. The tuning process is faster—less than 10 minutes—than manual tuning (up to 2 hours). The associated fabrication processing time has also been reduced, from more than 12 hours to less than 4 hours.

In the gigahertz band, components are quite small and tuning methods, such as using a tuning slug in a wire-wound inductor, do not work well. The size of a gigahertz wire-wound inductor is approximately the same size as the lead in an ordinary pencil. Producing a precise slug and installing it can be difficult. The tuning of high-frequency filters is accomplished typically by "physically spreading or closing the distance between turns of a coiled-wire inductor or snipping the length of a pair of twisted wires whose inter-wire capacitance is one of the filter elements."[1]

The standard approach (the baseline approach) to filter tuning prior to this project was to physically spread or close the distance between turns of a coiled-wire inductor. This method

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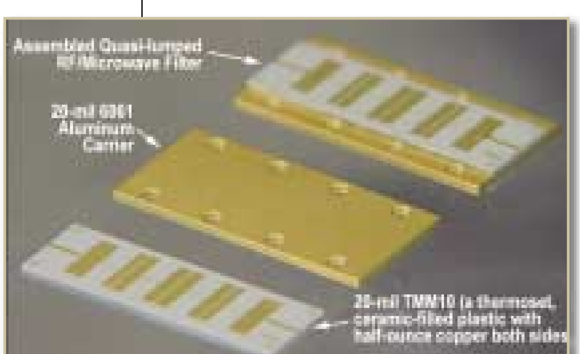

Fig. 1 A quasi-lumped RF/microwave filter replaces the conventional coil-wire inductor type in the automated tuning system.

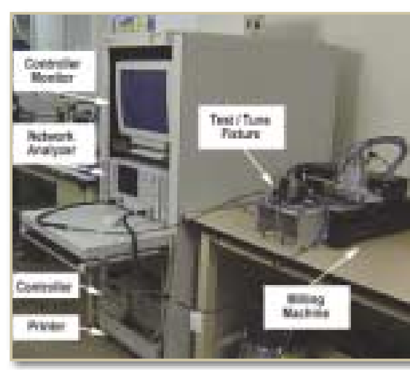

Fig. 2 The automated tuning station can trim, tune, measure, record, and log data for a number of different filter types.

Fig. 3 The test/tune fixture of the tuning station has two positions on a precision slide for either testing or tuning.

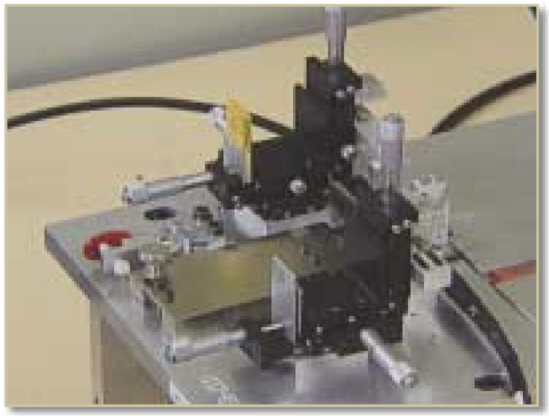

Fig. 4 In the test position shown here, the network analyzer compares data from the filter under test with information stored in a data base.

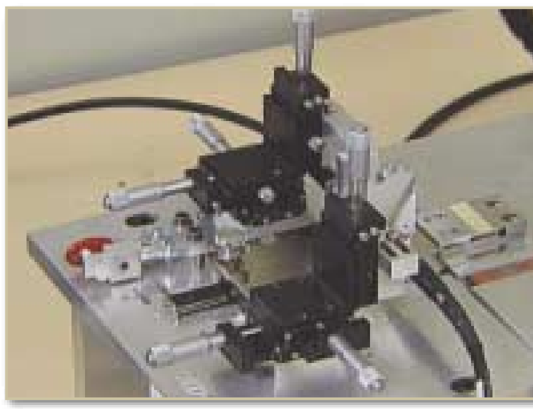

Fig. 5 Once it is determined as to how the filter will be trimmed, the filter is moved to the milling position.

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required hand-staking the inductor at a set temperature, the presence of a highly trained technician, a hand-generated data sheet, and a significant amount of "touch labor." The average tuning time by this method was between one and two hours.

A new automated process was developed to replace the coiled-wire inductor with a planar type of quasi-lumped RF/microwave filter constructed with distributed shunt capacitors, series capacitors, series inductors, and lumped-series capacitors on the input and output ports **(Fig. 1).** The tuning process involves the removal of material from the shunt-capacitor pads to achieve the desired performance. The advantages of this method over the baseline are quite apparent: no inductor staking is required, a less-skilled operator can perform the tests, the data are computer generated, and minimal touch labor is required.

An automated tuning station was developed following a study of material-removal methods and equipment. Filter performance was determined by a parametric study of the amount of material to be removed for a particular filter configuration. The study included the impact of the removal of substrate material on overall filter performance. The automated tuning station is shown in **Fig. 2**. Its main components include a milling machine (LPKF ProtoMat 91s/Vs), a network analyzer(HP 8720D), computer controller, printer, and custom-designed test/tune fixture.

The test/tune fixture consists of a two-position filter holder mounted on a precision linear slide (back position for testing, front position for tuning) mounted on the front of the milling bed **(Fig. 3)**. In the test position, the controller uses the network analyzer to compare the measured data taken from the filter to a stored data base of expected performance for that filter **(Fig. 4)**. The necessary trimming procedure—unique for each filter—is then determined.

Fig. 6 In the milling position, the milling machine is directed by the controller to tune the filter by removing metallization from the circuit.

The filter is then moved to the milling position **(Fig. 5)** where the controller directs the milling machine to tune the filter by removing metallization from the circuit **(Fig. 6)**. The depth of the cut is set manually in 1-mil increments using a micrometer adjustment on the milling head. The filter is cycled between the testing and tuning positions until the desired electrical performance is achieved. Upon completion of the tuning cycle, the controller prints out a data sheet for the next level of assembly and stores the information in a data base. Several types of filters can be tuned with this method, including quasi lumped-element, resistively damped, and interdigital types.

The automated process can tune a filter in 10 minutes or less, a significant reduction in tuning time from the baseline process. In addition, the time saved in associated fabrication processes further reduced production time. Eliminating the inductor staking together with shorter times for substrate curing, assembly, and tuning results in a total time savings of 10 hours per filter. It is anticipated that further improvements in analysis software in conjunction with parametric studies can determine the required physical configuration of filters. This will enable the precise etching of a filter, completely eliminating the need for tuning. The tuning process has been applied initially to S- and C-band filters used in the Patriot Advanced Capability 3 (PAC-3) Air Defense System. MRF

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