

## **Title: FBAR**

**Abstract:** The first FBAR filter/duplexer sold in 2001. By mid-2008, over one billion FBAR filters, in the form of filters, duplexers and multiplexers have been sold. This huge growth phenomenon can be attributed the excellent performance of the FBAR resonator. The use of AlN as the piezoelectric material coupled with high Q molybdenum or tungsten electrodes in a free standing membrane configuration leads to Q's over 3000, coupling coefficients of 7% and more recently, temperature stable resonators with performance comparable to quartz resonators (in terms of raw temperature stability and  $f \cdot Q$  product). This workshop will be broken down into 3 sections; the first section will consist of an Introduction and review of the two models used to model FBAR devices: the mBVD model and the Mason Model. This will be followed by a review and derivation of Q for piezoelectric resonators. Out of these discussions, Figure of Merit (FOM) equations will be derived with a follow up discussion on their role in comparing resonator technologies for use in commercial applications.

The next section will cover FBAR technology (what is it, how is it made) and will focus on the latest data from studies using an Acoustic Imaging Microscope. The mechanics of the microscope will be covered as well as the resultant dispersion curves for a variety of devices in the FBAR family (these include, W electrode devices, Mo electrode devices, SMR-BAW devices, CRF and zero drift resonator FBAR devices).

The last section will focus on next generation FBAR devices including FBAR Coupled Resonator Filters (CRF), and temperature stable FBARs (Zero Drift Resonators or ZDR). This section will cover the basics of single end to differential filters (aka unbalanced to balanced) devices using CRF and will also discuss various oscillator building blocks that have been demonstrated using FBAR oscillators.

**Bio:** Rich Ruby (PhD. U. C. Berkeley) started work on FBAR in 1993 while at HP Labs and continues today as Director of Technology for FBAR at Avago Technologies. Rich was made Fellow at Agilent in 2002 and remains a Fellow in Avago and has close to 80 patents (most of which are on FBAR). He has given two invited papers on FBAR at the Ultrasonics Symposium (one in 2001, and again in 2007).

**Bio:** John Larson joined Rich in 1996 on the FBAR project as the Acoustics Expert and has remained one of the strongest creative forces behind FBAR to date. John was the first to champion CRF in Agilent (now Avago) and has invested considerable time making and refining the Acoustic Imaging Microscope -- which is now in high demand by all the Program Managers looking for diagnostic support on their FBAR related projects.