## Circuit- and Electromagnetic Field Co-Simulation

**Results in Improved Microwave Design Models**

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### Microwave Circuit Design

**Design Procedure**

When designing microwave circuits at 1 to 100 GHz, accurate modeling is the key to success.

Microwave board level design allows for the use of a wide range of components and board materials in different technologies. The lack of accurate component models can be a problem. Package parasitics are important and hard to model, and interconnects are physically long, so distributed models are needed.

Microwave chip design is restricted to a specific semiconductor technology, but the device features and parasitics are small, and lumped models are accurate up to high frequencies. But component parameter tolerances can be high and are subject to gradients over the die.

Field simulations can predict the high-frequency behavior very accurately, and overcome the limits of a pure circuit description, but require massive computing power. Circuit (Kirchhoff) and field (Maxwell) co-simulation can improve microwave design considerably.

### Microwave Oscillator

A two-stage coaxial resonator oscillator working at 2.445GHz (ISM band) was designed. The high-Q coaxial resonator model (Q-factor and resonance frequency) was defined by linear measurements. Board parasitics extraction correctly predicts an oscillation frequency shift of more than 200MHz!

The oscillator has been optimized for maximum gain and minimum noise figure by open-loop analysis. The two stage design combines the benefits of low oscillator phase noise and high output power (measured to be 7dBm).

### Microwave Mixer

A single balanced down conversion mixer is designed to convert 2.4-2.5GHz MW signals to a lower IF.

MW/LO

**Combined Antenna-Low Noise Amplifier 2.4-2.5 GHz**

A low noise amplifier (LNA) is used in MW front-ends to reach a high sensitivity. But attenuation in the interconnect between the antenna and the LNA results in an equivalent degradation of the system noise figure.

A noise figure below 0.6dB over the entire ISM band.

An available gain above 14dB and a gain ripple between ±0.5dB.

Good overall stability is obtained by resistive loading at low frequencies.

### Doppler radar experiment

The use of a Doppler radar to detect speed violations of moving vehicles is well known. The radar transmits a continuous sine wave. An object approaching the transmitter reflects part of this sine wave at a slightly different frequency. By mixing the weak received signal with a sine wave at a slightly different frequency, the frequency shift can be down converted and recovered.

A metal pendulum of 3 cm diameter is swung in front of the antenna system at 1 meter distance. Spectrum analysis of the Doppler signal reveals the pendulum's period and the exponential decay of the swing. A person moving in front of the system creates strong bursts in the spectrum. Despite the low transmitted power of 2mW, motion detection at walking speeds is possible with a high signal to noise ratio. This illustrates the excellent noise figure of the antenna-LNA combination.

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