Dynamic Downconversion Module for MR Applications

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Introduction

A small down-conversion module was developed for 1.5T and 3T MR imaging subsystems to allow for dynamic amplification and increased system modularity. This module is required within the system to place the frequency of the MR signal within the frequency range of an analog-to-digital receiver board. Noise figure, linearity, and amplification were optimized in this 1-inch by 2.5-inch module, which can be used for "mix-on-coil" surface coil development or within large switching matrices.

Methods

The down-conversion module, or DCM, has been constructed on FR4 substrate using off-the-shelf components. The DCM is a stand-alone module that accepts pre-amplified MR signal input, a local oscillator signal, and control lines and outputs a down-converted signal (the same signal at a lower frequency). A subsystem picture is shown below.

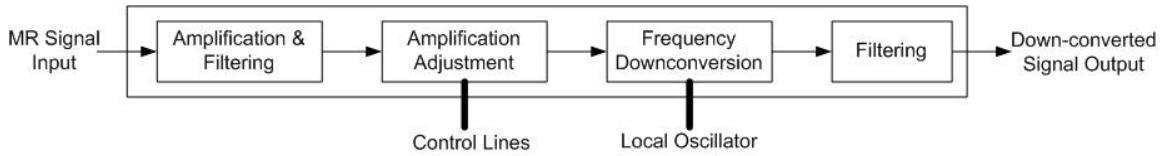

Figure 1: DCM Block Diagram

The module is constructed to allow step-by-step reduction of amplification depending on the amplitude of the MR signal entering the unit; a typical DCM gain level setting is 25dB, which indicates a low input level. To meet system requirements, the RF amplifiers, RF attenuators, and mixing components of this module were selected based on noise contribution, 1dB compression levels, and inherent gain/or loss within the component. Equation 1 shows how noise figure (NF) and amplification level (G) of each DCM subsystem affects overall module noise contribution.

$$NF_{overall} = NF_{Amp/Filter} + \frac{NF_{AmpAdj} - 1}{G_{Amp/Fitler}} + \frac{NF_{Downconv} - 1}{G_{Amp/Fitler} G_{AmpAdj}} + \ldots$$

Equation 1: Friis' Formula for Noise Figure

Band-pass filters were designed using low-level components such as inductors and capacitors. This placed a great deal of emphasis on the board layout; therefore, ADS Momentum software was used to determine optimum PC board trace and component placement to generate the desired filter characteristic. A DCM filter subsystem is modeled in Momentum on the right. In this image, inductor coupling is being examined; inductor coupling can decrease signal to noise ratio and skew the expected filter performance, leading to poor image quality. Momentum was also used to help "shrink" the DCM to its current size, which both a requirement for mix-on-coil applications and necessary to keep switch matrices to a manageable size.

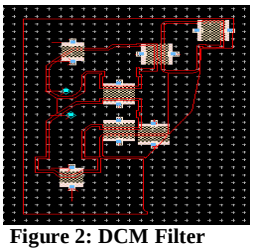

Figure 2: DCM Filter simulation

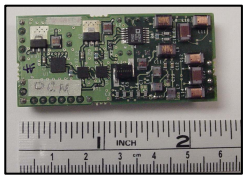

Figure 3: DCM Picture

Results

A picture of the DCM developed for 1.5T and 3T MR imaging subsystems is shown below. This module, at maximum amplification, has excellent noise figure (5dB) and linearity performance (OIP3 compression >20dBm).

Conclusion

A small down-conversion module was successfully developed for 1.5T and 3T MR imaging subsystems. This low noise figure, high linearity device allows for dynamic amplification of MR signals and increases system modularity.

References

C. Bowick. RF Circuit Design. USA, 1982 ed.
P. Vizmueller. RF Design Guide. USA, 1995 ed.