A NOVEL DSM BASED ALL-DIGITAL IQ MODULATOR FOR A HIGHLY EFFICIENT MRI TRANSMITTER

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PURPOSE

Delta Sigma Modulation (DSM) is a very promising technique to generate digital modulated signals and gaining high interest for all-digital transmitter architectures. In an all-digital transmitter, the switch mode RF power amplifier[1] magnifies the digital signal with high efficiency; and the narrowband antenna filters the digital signal to recover the analog information. So, high efficiency is maintained through the RF chain up to the antenna. All-digital transmitter architecture sounds a good candidate to an MRI system, which employs high-Q RF coils. In this study, a digital modulator which enables frequency, phase, amplitude modulation and efficient use of power spectrum, is presented.

METHODS

In a conventional MR imaging operation, it is critical to have more than one carrier frequency to shorten scan time. If multi-band signal generation is implemented at baseband in a conventional I&Q modulator, double side band (DSB) modulation occurs which then reduces amplification efficiency by %50. In this proposed all digital modulator, the signal modulation is provided all digital and unwanted band can be suppressed with digital Single Side Band (SSB) modulation. In the proposed digital architecture, multiband is generated at baseband with a CORDIC algorithm in an FPGA, which then results in high frequency resolution (down to mHz) between multi-bands (Fig 2). Conversion of analog to 1-bit digital data is implemented by Delta-Sigma modulator and then is injected into a Weaver SSB modulator. Then, SSB modulated I and Q circuitries are summed to form DSM based I&Q modulated digital signal at the desired radio frequency. The architecture requires a good frequency planning throughout the RF chain to avoid aliasing.

RESULTS AND DISCUSSIONS

The proposed all digital I&Q modulator (Fig.1) was implemented in FPGA. The measured spectrum of the FPGA output is shown for a frequency modulated multi-band sinc signal in Fig.2. The modulated signal contains 5 discrete frequencies, spanning 64.001 to 64.005 MHz with 1 kHz steps. The carrier frequency (64 MHz) rejection is achieved to be 40dBc. Frequency spectrum efficiency is maintained by suppressing the lower sideband components, as shown in Fig 2. The lower sideband rejection is larger than 50 dB. The digitally modulated time signal at the FPGA output is shown in Fig. 2 (top-left). This constant envelope DSM signal can be amplified by a highly efficient switch mode RF power amplifier. The analog information with 5 carriers can be extracted from the DSM based digital signal with a high Q filter. The filter bandwidth should be comparable with the signal bandwidth to gain SNR

CONCLUSION

The proposed digital modulation architecture takes advantage of a digital single side band (SSB) modulator to save power; and a CORDIC algorithm to generate frequency modulated MRI signal with very high resolved frequency steps. The digital stream with constant envelope can then be amplified with an RF switch-mode power amplifier (Class D,E,F,etc.). So, high efficiency is maintained in an MRI application.

REFERENCES

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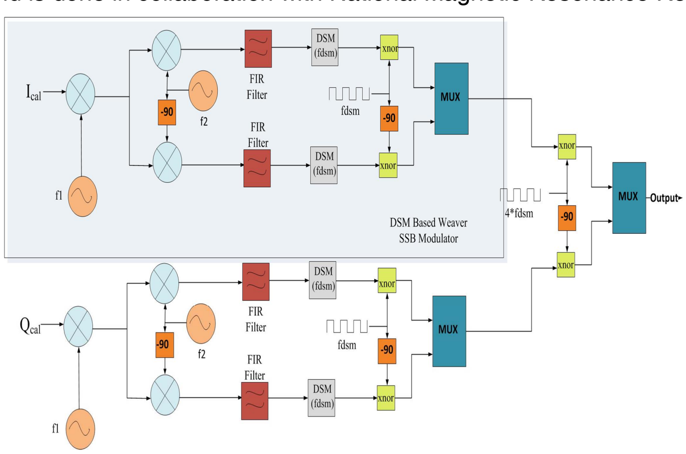

Fig 1. Block diagram of the proposed all digital DSM based IQ modulator

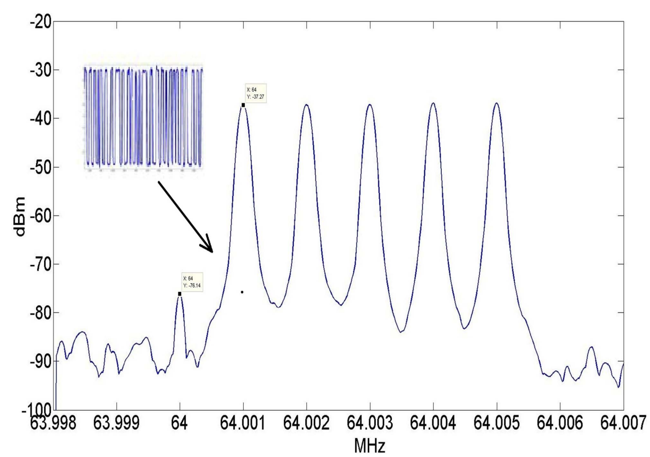

Fig. 2 Measured frequency spectrum of the proposed modulator output and corresponding digitally modulated time signal (top-left)