

# WIRELESS LOCAL COIL SIGNAL TRANSMISSION USING A PARAMETRIC UPCONVERTER

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## Introduction

Today's MR imaging systems use coaxial cables to carry the signal from the local coils near the patient surface to the receiver and the subsequent image processing unit. The cables involve some handling overhead as they have to be laid across the patient, and plugs have to be connected by the operator. In addition, the transmitting body coil can potentially induce common mode currents on the cable shields, which have to be suppressed by resonant traps. Obviously, a completely wireless signal transmission concept would be advantageous [1], [2].

The idea of a wireless coil system based on a low-noise parametric upconverter was presented recently [3]. The local coil unit is illuminated by a microwave local oscillator field which provides both the power required for signal gain and the frequency and phase reference for the upconversion. Thus, in analogy to field-powered RFID tags, no onboard power sources like batteries are required.

## Basic principle and experimental setup

A parametric upconverter is a mixer based on a nonlinear reactance (e.g. a varactor), converting power at one frequency to power at another frequency. As the mixing process ideally involves no resistive losses, a parametric mixer can be a very low noise device.

The power conversion between the frequencies is described by the classic Manly and Rowe equations [4]. For a lossless reactive upconverter with only three frequency bands involved, these equations are:

$$\left. \begin{aligned} \frac{P_s}{\omega_s} + \frac{P_h}{\omega_h} &= 0 \\ \frac{P_p}{\omega_p} + \frac{P_h}{\omega_h} &= 0 \end{aligned} \right\} G_{MR} = \frac{-P_h}{P_s} = \frac{f_h}{f_s} > 0 \quad (1)$$

with  $f_s$  and  $P_s$ ,  $f_p$  and  $P_p$ ,  $f_h = f_p + f_s$  and  $P_h$  referring to frequencies and powers of the MR input signal, local oscillator "pump" frequency and upconverted upper sideband output respectively. Negative powers designate power flow away from the mixer. Equation (1) shows that a parametric upconversion to the upper sideband is always accompanied by a positive power gain greater than unity.

For an initial experiment in a Siemens Tim-Trio MR system, an on-coil varactor upconverter ( $f_s = 123, 2$  MHz and  $f_p = 3$  GHz) was designed. A pair of patch antennas was used for each of the two microwave links. The received signal at 3.1232 GHz was further amplified, mixed down back to the original frequency and transferred to the standard MR receiver.

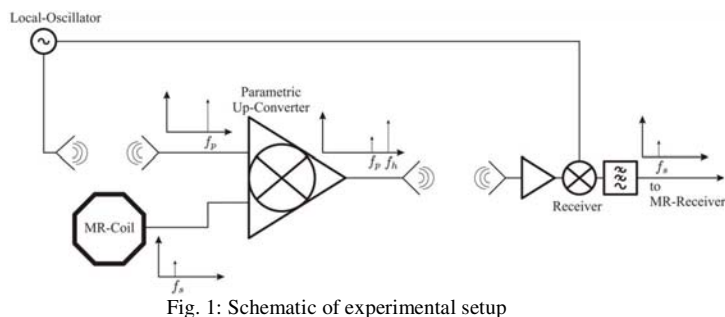


Fig. 1: Schematic of experimental setup

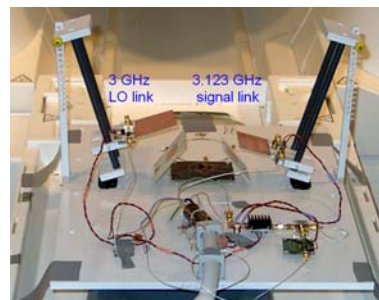


Fig. 2: Setup at scanner on a phantom

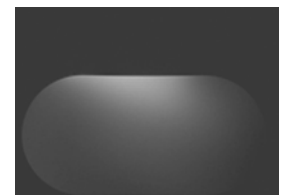


Fig. 3: Received phantom image

## Results

In bench top measurements, the parametric upconverter was driven by 10 dBm LO power and produced 11.9 dB gain, reasonably close to 14.0 dB as predicted by the frequency ratio. The noise figure was 1.0 dB, mostly originating from losses in the input impedance matching network of the diode.

In this first experiment, the SNR in the image of Fig. 3 was about 15 dB lower than the SNR of a standard coil. This large loss was mainly caused by a scarcity of LO power, resulting in a lack of upconverter gain which could not overcome the microwave link loss. However with an optimized upconverter design and a larger microwave receiving aperture (such as a large microwave antenna array located close to the body coil), we expect to get results comparable to state of the art wired coils.

## Conclusion

A wireless local-coil MRI signal transmission based on a microwave parametric upconverter was successfully demonstrated for the first time. Further research will focus on improving the system noise figure by increasing upconverter gain, and by collecting a larger part of the radiated power with an extensive microwave antenna array.

## References

- [1] Leussler, C.; Patent US 5245288
- [2] Vester M.; Patent US 6791322
- [3] Heid O., Vester M.; Patent US 6906520
- [4] Blackwell L. A., Kotzebue K. L.; Semiconductor-Diode Parametric Amplifiers; Englewood Cliffs: Prentice-Hall, 1961