A van Vaals Resonator with a Novel Quadrature Drive Circuit

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Introduction: High performance, quadrature volume coils find application in both MRI and *in vivo* spectroscopy applications. Technical problems encountered in the design and construction of coils includes dielectric losses and propagation losses; reactive elements placed near the specimen are often problematic. We describe here a technique for driving a van Vaals resonator [1] with a pair of ***current*** baluns [2], resulting in a quadrature volume coil with excellent performance and inherent multinuclear capability. In addition, this design provides for control of both power and phase in each conjugate pair comprising the resonator. Scaling the resonator up to 8 element and 16 element versions is straightforward, and the design lends itself to use in widely available clinical magnets.

Materials and Methods: A four element van Vaals resonator was constructed from Lucite tubing with machined Lucite end plates. Inside diameter was approximately 4.5 cm, with a length of 20 cm. A Faraday shield was formed by overlaying copper tape on the inside surface of the Lucite tube. Gaps of approximately 0.5 mm were incorporated for eddy current suppression. The end plates were also overlaid on the inside surface, and circumferentially with copper finger stock, thus ensuring electrical continuity throughout the entire Faraday shield. Four nonmagnetic female N connectors (Huber and Suhner) spaced 90 degrees apart were placed in each end cap. Center conductors composed of 6 mm OD copper tubing spanned each pair of N connectors by snapping into silver plated fuse clips soldered to the center pins of each N connector. Each of the four floating conductors was suspended symmetrically from the center of the resonator at a distance of about 2 cm above the Faraday shield. Quarter wave open circuit lines [3] were constructed from RG-213 cable and male N connectors, or from fabricated sections of air dielectric coax with male N connectors Electrical lengths of all feed lines and open circuit lines were measured using a HP 8405A vector voltmeter and a HP 778D dual directional coupler. Sets of stubs and lines were matched to within less than 0.5 degrees. Conjugate matching was achieved with variable length air dielectric coaxial line "stretchers" (Microlab FXR SR-50N) shunted with high Q variable piston capacitors (Voltronics). This approach eliminated the need for any series "tune" capacitors. Current baluns were constructed by slipping #43 mix ferrite beads over RG-303 coaxial cable, or by winding lengths of RG-213 cable into solenoids with sufficient inductive reactance for outer shield current suppression. The output of each balun was connected to a pair of line stretchers via matched lengths of coaxial cable, forming balanced, shielded feed lines. Circular polarization was achieved by feeding the balun inputs via a quadrature hybrid combiner (Anaren), or via a simple phasing harness constructed from a quarter wave section of 50 ohm line combined with two 75 ohm quarter wave matching transformer lines. The coil is shown in Fig. 1.

FIG. 0 The disassembled van Vaals resonator. Picture shows the resonator (a), current baluns (b), matching capacitors (c), open circuit stubs (d) and line stetchers (e).

Results: After conjugate matching ("tune and match"), the coil was loaded into a 3T GE clinical scanner. Phantoms of distilled and deionized water, 0.45% saline, 0.25% saline, and mineral oil were used for T1 weighted images, spin echo images, and gradient echo images. A representative spin echo image is shown in the Fig. 2. This axial cut went through the neck of the small polyethylene bottle from which the 0.45% saline phantom was constructed. During the acquisition of this image, a 90 degree flip angle was attained with approximately 10 watts of power measured at the inputs of the line stretchers. An axial cut through three stalks of celery is shown in Fig. 3 which illustrates the spatial resolution of this coil. This 4 element test coil has demonstrated good performance with a signal to noise ratio (SNR) of 119 and spatial resolution of 160 microns or better. Note the vascular elements in the celery images.

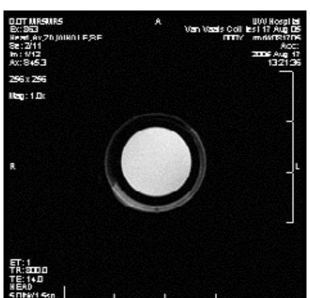

FIG. 2 Axial spin echo image of 0.45% saline SNR phantom. Measured SNR = 119

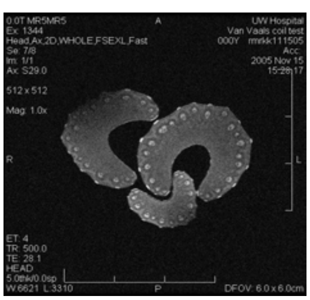

FIG. 3 High resolution (512x512) cross sectional image of celery (FOV = 8cm)

Discussion: A four element transmit/receive van Vaals resonator with a novel quadrature drive circuit was constructed and tested. The coil demonstrated excellent efficiency and mimimal loading effects. While retaining all of the attributes of the original van Vaals resonator, this quadrature van Vaals coil offers control of both phase and power in each conjugate pair; this may have implications for transmit SENSE applications. Like the original van Vaals resonator, it offers inherent multinuclear capability as all tuning elements are remote from the resonator itself. The coil is compatible with widely available clinical magnets, and could be readily scaled up in size for clinical applications in 1.5T and 3T scanners.

References:

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