## *Theoretical Lecture*

## *Surface coils, phased arrays coils& Quadrature coils*

### *Surface coils*

**Surface coils** are basically receiver only coils, used closer to the imaging part, e.g. lumbar spine, and knee. They receive signals effectively from a depth provides smaller voxel, better resolution, but have smaller FOV and less uniformity.

Receiver coils provide larger signal, lesser noise, and improve SNR (signal to noise ratio).

In The shape of **surface coils** which is usually a circle, which will facilitate the fabrication of coil. Figure1

Figure1: RF surface coils.

***The reason of that surface coils are often used as receivers is***, that the field it produces is inhomogeneous, which is detrimental to the imaging process. But the signal-to-noise ratio (SNR) of the surface coils is higher than volume coils, partly because it can be located closely to the imaging area.

Nowadays, surface coils are not used alone to achieve the receiving purpose. A bunch of surface coils, which we call loop array (phased array), are used for its good performance in receiving as well as transmitting. An illustration of surface coil and array coils are shown in **Figure** 2.

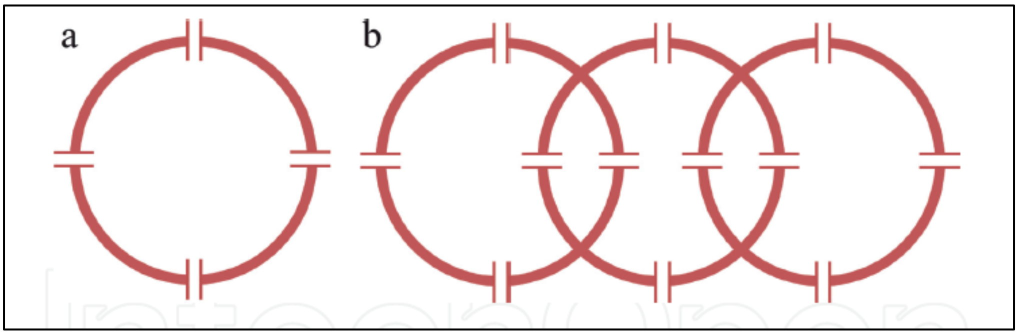


**Figure 2:** *Diagram of surface coils: (a) single coil and (b) array coil.*

***Phased array coils:***

**Array coils** systems are collections of small surface coils whose signals may be combined but generally feed into independent receiver circuitry. Small-diameter surface coils near the patient have high sensitivity but limited anatomical coverage. By combining multiple small coils into large arrays it is possible to obtain the best of both worlds high signal to noise and large fields of view.

Figure 3: array coils.

**Phased array coils**, four or more receiver coils are used and they receive signal individually and then combine the signal. This makes the signal less noise, high SNR with large FOV. An illustration of surface coil is shown in **Figure 2** and **Figure 4**.

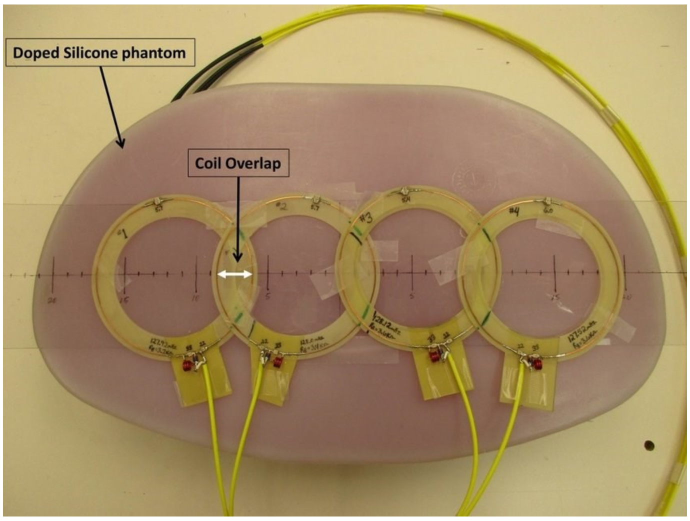


Figure 4: Four element phased array coil.

Transmit phased array coils produce current on each element and have special amplifiers. The control of amplitude and phase make them independent. It employs reduced pulse duration, with higher SNR, improved field homogeneity.

## *Quadrature coils*

A coil that produces an RF field with circular polarization. The RF power received from the RF power amplifier comes in two signals (quadrature detection), which have a phase difference of 90Â°. The RF transmit coil converts the power into a circularly polarized RF magnetic field.

Quadrature coils can be used as both, transmit and/or receive coil. When used as a transmitter coil a factor of two power reduction over a linear coil results; as a receiver an increase in SNR of up to a factor of 2, can be achieved.

Figure 5 shows a Helmholz pair of coils arranged in a linearly polarized (LP) configuration. The B1 RF-field (green arrows) is generated by driving the coils with a sinusoidal electric current, causing B1 to oscillate back and forth in a single direction (coil 1). By adding a second set of coils perpendicular to the first and driving them with sinusoidal current phase shifted by 90°, a pure rotating B1 field can be created.

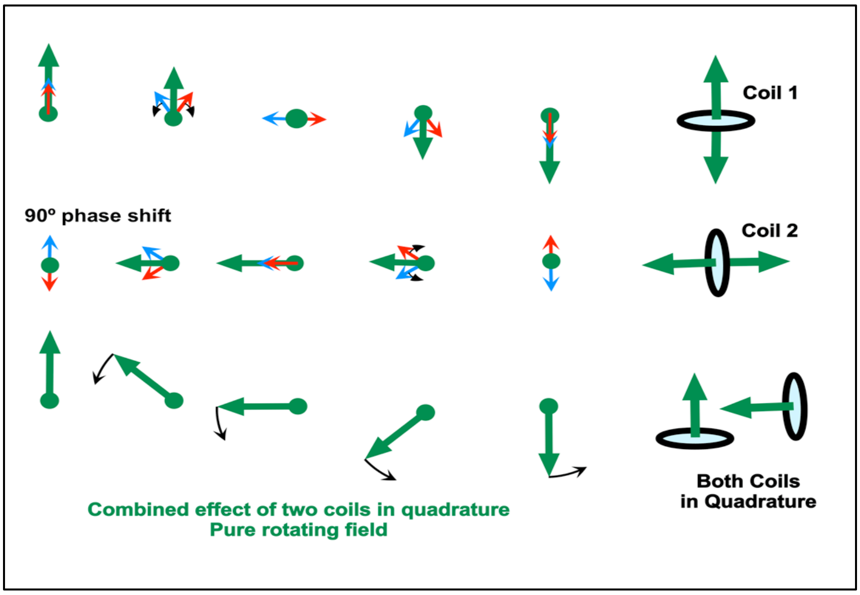


**Figure 5:** Vector diagram of two linearly polarized coils placed in quadrature. Each is driven by a sinusoidal current, but Coil 2 is 90° out of phase with Coil 1. The oscillating field from each coil can be decomposed into vectors rotating in the same direction as the spin system (blue arrows) and in the opposite direction (red arrows). When added together the net effect is a rotating B1 field without wasted power.

This is known as ***circularly polarized (CP)*** or ***quadrature transmission***. The unwanted counter-rotating fields from each linear coil set (denoted by red arrows below) are always 180° out of phase and hence cancel each other out. The useful subfields in sync with the spin system (blue arrows) add together vectorially to produce a rotating B1 field with no wasted power.

Like LP coils, CP coils can be used as transmitters, receivers, or both. The most common type of quadrature RF-transmit coil used in MRI is the ***birdcage coil*** or the ***transverse electromagnetic (TEM) coil***.

### *1- Birdcage coils:*

Birdcage coils are an example of circularly polarized coils or quadrature excitation.

The birdcage coil is the most commonly used RF-transmit device used in clinical MRI today. As shown in figure 6, the birdcage coil consists of two circular conductive loops referred to as end rings connected by an even number of conductive straight elements called rungs or legs. The number of rungs depends on the size of the coil (body coil > head coil) and typically ranges from about 8 to 32.


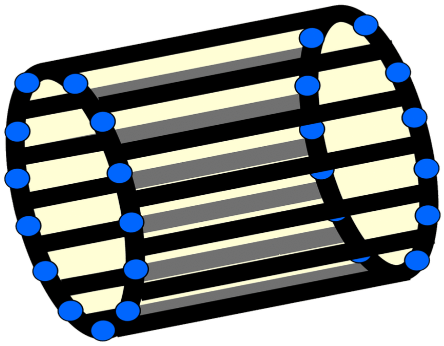

Figure 6: figure shows Birdcage coil

***2. Transverse electromagnetic (TEM) coil***

***A TEM resonator differs from a birdcage coil in the following ways:***

1. The TEM coil typically uses foil microstrips instead of rods affixed to the inner surface of a nonconducting cylinder (figure7).
2. On the outer surface of the cylinder is a slotted thin metallic shield.
3. Birdcage coils provide excellent homogeneity at fields below 3T while TEM uses at ultra-high field (3T).
4. Unlike a birdcage coil, the TEM's inner conductors do not connect to their closest neighbors, but instead connect directly to the shield through tunable capacitive elements that can be adjusted to achieve the best homogeneity .


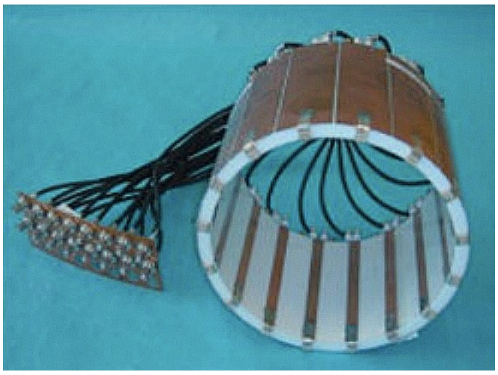

Figure 7: figure shows TEM coil.

***Questions:***

1. Why surface coil are often used as receiver?
2. What are the array coils؟
3. What are phased array coils؟
4. Draw the diagram of single surface coils and array coils?
5. What is quadrature coil?
6. What are the differences between the birdcage coils and TEM coils?