microcoil. Hence, by monitoring OUT **2**, a change in microcoil inductance due to a magnetized sample (e.g., a bead-bound cell) can be determined, thereby indicating the presence of a sample.

[0165] In one aspect of the embodiment illustrated in **FIG. 20**, low-noise design may be significantly advantageous to realize high-accuracy RF sample sensing, given that the microcoil inductance change ΔL due to a single magnetic bead, as discussed above, may be as low as 0.1~1% in some exemplary cases. Accordingly, in one exemplary implementation, the frequency synthesizer **4802** may be implemented using significantly low-noise high frequency oscillators based on coplanar striplines, similar to those discussed in U.S. Non-provisional application Ser. No. 10/894,674, filed Jul. 19, 2004, entitled "Methods and Apparatus Based on Coplanar Striplines," and U.S. Non-provisional application Ser. No. 10/894,717, filed Jul. 19, 2004, entitled "Methods and Apparatus Based on Coplanar Striplines," incorporated by reference herein.

[0166] Having discussed the detection of a magnetic sample, various concepts disclosed herein relating to RF fields likewise may be employed for identification and characterization of samples of interest. For example, frequency dependent changes in either the electric or magnetic polarization of samples can be used to identify the type of sample, using knowledge of the behavior of various materials in electromagnetic fields from conventional solid state physics. These changes may be characterized over a broad range of frequencies. Accordingly, in one embodiment, by sweeping the RF frequency of signals applied to field-generating components (or using more sophisticated signal processing techniques), the frequency response (e.g., absorption spectrum) of the sample can be measured at a particular location, and the sample may be identified or characterized based on the measured response.

[0167] In yet other embodiments relating to the application of RF fields and sensing of field/sample interactions under the control of the RF/detection components **480**, an RF field can be used to conduct local measurements of magnetic resonance in a uniform magnetic field applied to a sample. In particular, the spins or magnetic domains of a given sample oscillate with characteristic frequencies, which can be used to identify the type of spin or the sample itself. Magnetic resonance types include ferromagnetic resonance (FMR) (small YIG spheres may be used as magnetic beads, as each sphere has a single magnetic domain that rotates freely at GHz frequencies because the bead is spherical). Additionally, Electron Spin Resonance (ESR) techniques may be employed to identify the g-factor of the spins involved to characterize their origin (i.e., the sample), as well as Nuclear Magnetic Resonance (NMR) to identify the g-factors of the nuclear spins. Thus, according to the principles discussed herein, a Magnetic Resonance Imaging (MRI) system may be implemented on a chip.

[0168] IV. Temperature Regulation

[0169] As mentioned above in connection with **FIGS. 1 and 2**, according to one embodiment the hybrid system **100** may include temperature regulation components **500**. In exemplary implementations involving a significant number of field generating components **200** and accompanying field control components **400**, the power consumption of the system may be appreciable and operation of these components may increase the temperature in and around the system. In view of the foregoing, the temperature of the system may be regulated at or near a particular temperature to facilitate biocompatibility of the system with the cells/samples under investigation, and also to reduce the risk of electromigration failure as mentioned earlier.

[0170] More specifically, according to one embodiment as illustrated in **FIG. 21**, the temperature regulation components **500** may include one or more on-chip temperature sensors **500**A and an off-chip temperature controller **500**B. With reference for the moment again to **FIG. 2**, in various implementations multiple on-chip temperature sensors **500**A may be disposed at a variety of locations in and around the IC chip **102**; in **FIG. 21**, one exemplary temperature sensor **500**A is illustrated generally in the environment of the IC chip **102**, which is in turn coupled to the package substrate **110**. In one aspect of this embodiment, the one or more on-chip sensors **500**A provide one or more temperature signals T_{chip} to the processor **600**, which is shown for purposes of illustration in **FIG. 21** as a comparator that compares the signal T_{chip} to a reference temperature signal T_{ref} (in one exemplary implementation, T_{ref} may represent a temperature of 37 degrees C.).

[0171] In various implementations, the processor **600** may be configured to receive multiple temperature signals from respective different on-chip sensors, and process the multiple signals according to one or more predetermined algorithms (e.g., averaging, weighted averaging based on chip location, etc.) to provide some aggregate sensed temperature value, which then may be compared to the reference temperature. Based on a comparison of one or more sensed temperatures and the reference temperature, a control signal is provided to the off-chip temperature controller **500**B, which heats up or cools down the package substrate **110** accordingly (e.g., a thermoelectric or "TE" cooler may be used as the off-chip controller **500**B in one exemplary implementation). In another aspect of this embodiment, the thermal conductivity across all the layers and within each layer of the IC chip **102** is such that the whole system can be assumed to be at the same temperature. Thus, the regulation loop is sufficient to keep the temperature of the overall system at a constant value.

[0172] In the embodiment of **FIG. 21**, the exemplary on-chip temperature sensor **500**A includes a parasitic pnp bipolar transistor **5002** and a reference current source **5004** (available in any standard CMOS process). If the transistor's emitter current is kept constant at a reference current I_{ref}, the emitter-base voltage of the transistor is given as

$$V_{EB} = -\log\left(\frac{I_{ref}}{I_S}\right)\cdot\frac{kT}{q}, \tag{9}$$

where the logarithm is base e, I_S is the leakage current of the transistor, k is Boltzmann's constant, q is the electron charge, and T is the absolute temperature. The above equation indicates that the emitter voltage can be used as a direct measure of the chip temperature (T_{chip}). In one embodiment, the processor **600** compares this emitter voltage to a calibrated voltage representing the reference temperature (e.g., T_{ref}=37° C.) using a 1-bit comparator. If $T_{chip}>T_{ref}$, a control signal provided by the processor operates the temperature controller **500**B to cool the chip, and vice versa.