Revision 1.0

Theory of operation

To talk to a backscatter device several events must occur.

1. The device must be told to wake up and begin backscattering.
2. The device must be able to backscatter energy back to a reader.
3. The reader must demodulate the backscatter data sidebands.
4. The reader must phase lock to the incoming data stream.
5. The system must decode the data.
6. The system must check for and correct errors in the data.
7. The system may need to correct for multipath or standing wave canceling effects.

Waking up a sensor or tag to tell it to begin backscattering

The entire goal of a backscatter system is to minimize cost and power usage in the tags. This means that the RF receive and demodulation systems must be very simple and most likely be based off of CMOS type sensors. Power is not available to drive an LNA so minimum detectable powers are on the range of -38 dBm. Demodulation is usually done through a thresholding circuit so modulation formats need to be simple. Our particular system receives and rectifies a broadband energy band centered around 2.44 GHz and then uses a comparator circuit to decode a biphase on off carrier datastream. This comparator circuit is the only circuitry generally consuming power in the system when receiving from a reader and so the current consumption is on the order of 2 microamps. The output of the comparator causes an interrupt to a microcontroller which decodes incoming pulses and time stamps them. A routine then sees if the incoming message is for that device and responds accordingly.

Backscattering data to a reader

After the message is sent to the tag the reader begins to broadcast a continuous carrier to the tag. If the last incoming message was meant for this tag, the tag follows the instructions of the message and then encodes a response to the message into memory. The unit then shuts off the receive circuit and begins to modify the reflection characteristics of the antenna so as to begin modulating data onto the reflected carrier. The reflected carrier is modulated either in amplitude or in phase or both. Phase modulating the reflected carrier has more impact generally but some tags can use amplitude modulation easier. Our system uses both styles. The modulation frequency is set by the tag's internal clock which is a fractionally multiplied version of the timekeeping crystal on board the tag. The tag then begins to change the system clock so as to encode data in a delta FSK fashion which relieves the reader from having to greatly oversample the incoming waveform. The FSK modulation provides a subcarrier onto the reflected signal usually several MHz away from the carrier frequency.

Demodulating the backscattered data sidebands

The reader then multiplies the incoming signal with the outgoing signal which strips the carrier off and leaves only the data signal at a low IF frequency at the tags current internal clock rate. This signal is then amplified and filtered and then fed into an A/D converter. It should be noted that any number of data signals could be come in at any one time so they system just passes an entire band of frequencies to the A/D converter so that they can all be processed simultaneously.

Phase locking to the data streams

A DSP then takes the sampled data and attempts to simultaneously lock to all the incoming tag datastreams. It does this by running a correlator on various sections in the band until all the data streams have been locked onto. It should be noted that since all of the tags probably began talking at slightly different times, the point where the DSP locks to some tags and begins decoding the data, is different for each tag. Once a positive correlation occurs on a particular data stream the spectral analysis begins tracking frequency changes for that particular carrier at the same time as following it's amplitude to discriminate it from other carriers in the same band. These frequency changes or deltas are then looked up in a table to decode the data. Every frequency delta corresponds to several bits of data.

Checking for and correcting errors in the data

Once the data is decoded it is then checked for errors in transmission. To ease this task every message has a CRC appended to it and each message is rebroadcasted by the tags so that it can be rechecked or corrected if errors were found.

Compensating for multipath and standing wave issues.

Since our system relies on a reflected signal it is possible to have signals cancel out if they are 180 degrees out of phase with each other when they get back to the reader. This can be compensated for in several ways. One way to do so in hardware is to split the incoming signal into two pieces and to phase shift one of those by 90 degrees before multiplying them by the transmitted signal so that no matter what you always get a good signal. The other way that this is dealt with is to hop the carrier frequency by ¼ wavelengths at some given distance so that any nulls are removed at least once during the backscatter period. Since it is not know whether the tag got the previous wake up request a new one must be sent every time the frequency hops.