Designer antennas for RFID applications

The choice of the correct RFID antenna for a specific application is a complex issue. It is necessary to consider what elements of an RFID system are needed: from the spacing of antennas to the strength, shape and resonance of readers and transponders

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Some of the most critical elements of any RFID installation are the performance characteristics of the antenna system. The antenna is the main component for transferring energy from a transmitter to passive RFID tags, receiving the transponder's reply signal and avoiding in-band interference from electrical noise and other nearby RFID components. Long wave radio transmitters and nearby PC monitors are common sources of disturbances.

Custom antenna design may be required to optimise performance where the radio field must cover large areas or be focused on a specific area. The application may also require a specially shaped antenna that needs to be built around, or into, an existing space. Special field patterns may also be desired to avoid nearby sources of electrical noise.

Antenna performance

The reading range of an antenna is dependent on many variables:

- the quality of the earth to ground connection;
- the antenna size;
- the tag size;
- the tag's orientation with respect to the transmitting antenna;
- the antenna's location with respect to other materials;
- the ambient electrical and magnetic noise within the band of interest.

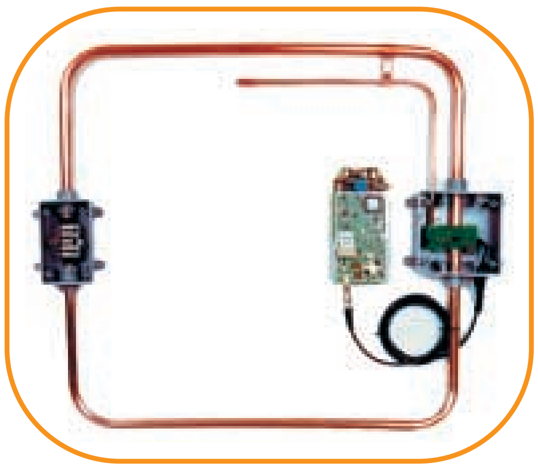
Low frequency transmission

TI RFID low frequency tags operate on a carrier frequency of 134.2 kHz. The "uplink" from the RFM reader (radio frequency module) to the RFID tag transponder is a Frequency Shift Keyed (FSK) transmission with a bandwidth of

25 kHz. The "downlink" from the RFID tag transponder to the RFM is an Amplitude Shift Keyed (ASK) transmission responding with identification and stored data information.
Traditional radio transmission comprises a combination of electrostatic field and magnetic field components. These fields are depicted as orthogonal vectors that propagate a transverse electro-magnetic (TEM) disturbance, which can be received at a distance from the source. Although low frequency RFID tags generate TEM waves, their magnetic component becomes the most significant source of energy transfer for the link of the near field.

As energy is transferred from the RFM to the antenna, magnetic flux waves extend into the space surrounding the coils. Similar to a transformer coupling energy from its primary winding to its secondary winding, the expanding field from transmitter antenna coils can induce a voltage in a second coil in its proximity, such as an antenna coil within an RFID tag present in the field. The induced voltage in the tag's coil is utilised to charge a capacitor. Acting as a temporary battery, the capacitor then

powers a chip that provides the data and the intelligent protocol for transponding back to the RFM. The ratio of turns between the RFM antenna coil and the RFID transponder coil determine the maximum voltage that can be induced by transformer action. By increasing the turns ratio of antennas, the induced voltage linking in one direction may increase, but the induced voltage linking in the opposite direction decreases. Just adding more turns to the RFM antenna does not increase performance; In fact it may have the opposite effect.



Dynasys gamma gateway 13.56 Mhz RFID antenna

Bigger is not always better

Reading performance does not necessarily increase when using a larger antenna. Although larger loops tend to yield wider coverage areas for transponder tags, noise from the environment may result in a worse "signal-to-noise ratio" at the receiver. A careful balance must be attained between the coverage area required and the reliability of the reception.
A 6 dB difference between signal and noise levels must be maintained to assure accurate readings free from background interference.

Antenna types

Antennas come in all shapes and sizes – one size does not fit all! When selecting the antenna type, which will optimise performance, you need to take into account size, shape, proximity to other materials, field pattern, cost and perhaps a number of other concerns.

Also, by utilising a multiple array of smaller antennas operational performance may be better than with one larger antenna.

Loop antennas

Small RFM antennas have less area than large antennas to transmit and capture energy. By increasing the number of windings of the smaller antenna more energy can be captured. However, as mentioned previously, the induced voltage in the RFID transponder is dependant on the turns ratio between transmitter and tag coils. More turns on the transmitter coil induce a stepped down voltage on the tag. Also, as the distance between the coils increases, less lines of flux are available to cut through each other. The loss of voltage due to the step-down ratio and loss of field lines can be offset by increasing the permeability of the core of couplings.
The number of turns in the loop is determined by the overall size of the antenna and how tightly the wires are packed together. The optimum number of turns for maximum range is also affected by the close proximity of metal. Metals with different magnetic permeability will exhibit different achievable ranges.

Stick antennas

Ferrite rods are used to increase magnetic flux density without appreciable energy losses at the transmission frequency. The concentrated flux lines at the ends of the ferrite rod focus the field pattern. This effect tends to increase the transmission distance while in this main lobe of the beam. The field outside of this main lobe decays rapidly with distance. Ferrite rods are utilised in both RFM antennas and within transponder tags.

Resonance

In order to transfer maximum energy from the RFM to its antenna system the antenna circuit (tank) should be tuned to resonate at the carrier frequency (for example 134.2 kHz). At resonance the capacitance of the circuit is balanced out by the inductance of the antenna coil. Antennas having a nominal inductance of 27 uH are ideal for standard low frequency RFMs. On-board variable tuning components should normally resonate antennas between 25.5uH and 28.5uH.

Quality factor – “Q”

A dimensionless figure of merit called the “Quality Factor”, or simply “Q” represents the relationship between effective impedance caused by the coil inductance at the frequency of transmission and the resistance of the antenna wire. The lower the resistance of the conductor the higher the Q.
A high Q antenna not only transfers maximum energy in resonance, but also has a narrow bandpass limiting out-of-band interference. Keeping the resistance of the coil approximately 0.3 Ohm will yield a Q typically near 100, offering increased performance and maximum immunity to background noise.

Proximity to metals

Altered performance of the RFID system can be expected when metals are in close proximity of the radiation field. Proximity to metals effectively lowers the antenna’s inductance. Lower inductance causes an increase in resonant frequency and also a reduction in "Q". Designers may consider starting with a higher-than-needed "Q" "in the lab", expecting it to be lowered when it is installed in its intended location. External capacitance may be required to tune the modified antenna system back to resonance. These types of situations can be experienced around conveyor belt structures and also embedded antenna loops on concrete driveways where metal re-bars absorb some of the radiated energy.

Skin effect

"Skin Effect" is the tendency of alternating currents to occur on a conductor's surface, rather than throughout the entire cross-sectional area of the conductor. At radio frequencies moving charges in the conductor cause a self-induced magnetic field which in itself generates a counter voltage. This self-inductance is greatest at the centre of the conductor and thus limits the current in that area. Electrical currents move toward the outer surface of the conductor where the counter electro-magnetic force is at a minimum.
To limit losses due to skin effect the conductors should have a maximum surface area to volume ratio. Multi-stranded, insulated, fine wire has more surface area than a single solid wire of the same overall gauge.

Antenna arrays

You may wish to use multiple antennas in order to cover a larger area or to alter the polarisation characteristics. Multiple loops may simply be directly connected together or "multiplexed" through intelligent antenna switches and matching networks to alter the tag detection patterns.
A good analogy of this is when you connect audio speakers to a stereo amplifier. Caution must be taken when attaching "+" and "-" leads to be sure that the sounds produced by each speaker are "in-phase" with each other.
If parallel antenna loops are connected "in-phase" then a strong field is produced between them. This field is ideal for operating tags that are oriented parallel to the loops. If they are connected "out-of-phase", also referred to as "anti-phase", the field is rotated and is ideal for a tag oriented at right angles to the loops. Anti-phase connection is used when noise reduction by phase cancellation is required.
Considerations must be given to the effective inductance of two individual loops connected in parallel. Note: Two 54uH loops connected in parallel will have a combined inductance of 27uH.

Practical implications

If you are buying or updating an RFID system then the considerations above will be of great significance to you. It is of paramount importance to ensure when readings are taken, that they are conducted in a sufficiently inert environment, free from sources of electrical, magnetic or liquid disturbances. Of equal relevance is the layout of guiding enclosures and the number, size, type, strength and operating frequency of antennas. It is the combination of these factors that will be difficult if not impossible to standardise. While RFID systems do present the client with a degree of flexibility, predictable design characteristics can help him make informed choices, based the final destination of units. The managers of companies using RFID applications will also need the help of specialised businesses to assess the correct types of antenna to use, if their aim is to maximise efficiency.