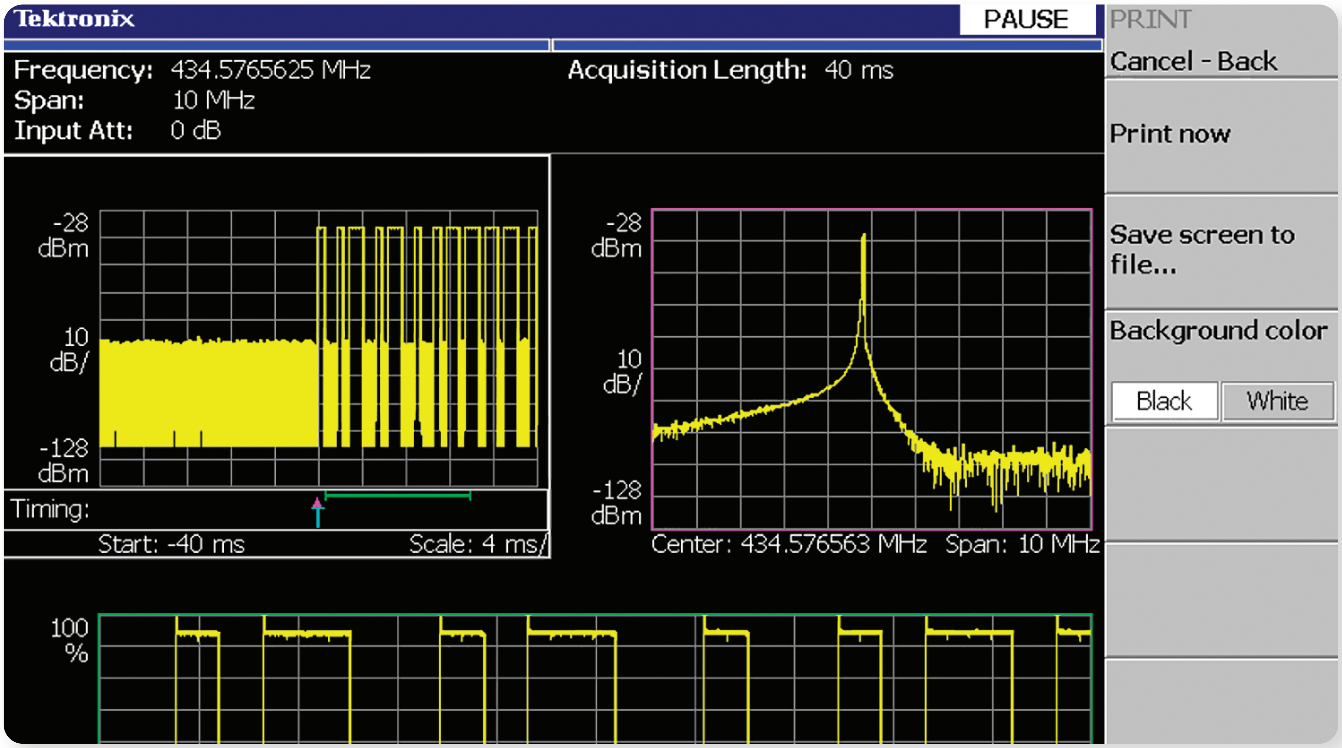
Radio Frequency Identification (RFID) Overview



RFID automatic identification technologies utilize low-power, short-range wireless communications technology to provide radically enhanced data handling capabilities.

Complimentary in many ways to other data capture technologies such bar coding; the RFID field already includes a range of devices and associated systems that satisfy an even broader range of uses. These uses include: commercial applications such as automated inventory control and ticketless entry; agricultural applications such as electronic tracking of livestock and improvement of food traceability; and transport applications such as automated toll collection, airline baggage tracking and vehicle management systems.

RFID technology allows the storage of data in tiny electronic transponder circuits that are extremely portable. Commun-ication between a transponder circuit and an interrogator is by radio or electromagnetic waves, so the stored data can be read and written without contact and very often through obstructions. This makes RFID systems very robust in the presence of dirt and dust. In addition, built-in anti-collision functions allow simultaneous access of multiple data tags, and communication checking functions such as special purpose protocols and Cyclic Redundancy Checking (CRC) provide high reliability.

Trends in RFID technology show that research and develop-ment continue to yield larger memory capacities, wider reading ranges, and faster processing. In the not too distant future, retail workers will be able to walk down an aisle of goods with an RFID reader and instantly obtain the inventory on the entire shelf. The reader will automatically categorize the items and provide an inventory count, making the entire inventory process more productive and efficient. The National Highway Traffic Safety administration is looking into RFID technology (DSRC), not only for toll tagging, but also for vehicle warning situations in which, say, a car approaching a curve too fast can be warned of excessive speed. As the technology matures, tags will become lighter, smaller and cheaper and be able to hold more information. Instead of a simple one or zero, or an ON or OFF signal, tags will send user name, account number and billing information.

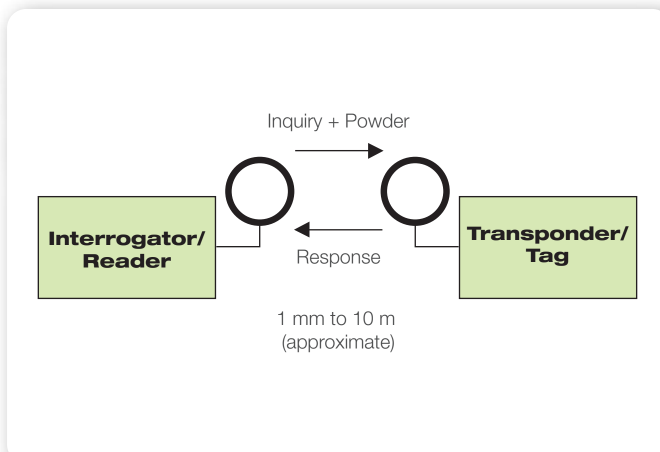
The ability to transmit personal data wirelessly will bring to the forefront the most important issue RFID system manufacturers will face – information privacy and security. As the future unfolds, RFID manufacturers will be tasked with ensuring that personal information is secure. Rigid adherence to regulations and standards, plus accurate R&D and production line testing will help manufacturers meet privacy and security expectations.

RFID technology overview

The object of RFID research and development is to create systems that will carry increasing amounts of data in trans-ponders (tags) of decreasing size. This data is designed to be wirelessly retrieved by electronic interroga-tors (readers) and may provide identification for: items in manufacture; goods in transit; the identity of a vehicle, animal or individual; or the location of any of these. RFID systems also require a means of communicating the data to a host computer or information management system.

Transponders/Tags

The word transponder, derived from **trans**mitter/res**ponder**, indicates how the device functions and suggests the essential components of RFID systems. The tag responds to a transmitted or communicated inquiry for the data it carries from the reader. The inquiry signal typically carries the power needed for the tag to send a response. The mode of communication between the reader and the tag is wireless RF across the air interface between the two (typically 1 mm to 10 m).



▶ **Figure 1.** *Simplified overview of an RFID system*

Generally speaking, tags are fabricated as low power integrated circuits that utilize "coil-on-chip" technology for data transfer and power generation (in a passive mode).

The Interrogator/Reader

The complexity and configuration of the interrogator/reader depends on the functions to be fulfilled, which can differ quite considerably from application to application. In general, however, the reader's function is to provide the means of communicating with the tags, and to facilitate data transfer. Functions performed by the reader may include quite sophisticated signal conditioning, parity error checking and correction. A command response protocol, for example, applies algorithms to signals received from transponders and correctly decoded to decide whether the signal is a repeat transmission. It may then instruct the transponder to cease transmitting in order to circumvent the problem of reading multiple tags in a short space of time. This is referred to as "Hands Down Polling", which is distinguished from an alternative, more secure, but slower tag polling technique called "Hands Up Polling". With this latter technique, the reader looks for tags with specific identities and interrogates them in turn in a process called is

contention management. A variety of wireless communication techniques have been developed to improve the process of batch reading.

Wireless communication

RFID systems typically utilize one of two methods of wireless communication – one is based on close proximity electromagnetic or inductive coupling and the other upon propagating electromagnetic waves. In addition, a radio wave propagation method is currently in deliberation at ISO for standardization, while other methods being considered are electrostatic and optical coupling.

The wireless link is achieved with antennas built into both tags and readers. Quite often an antenna is distinguished as if it were a separate part of an RFID system. While its importance justifies the attention it must be seen as a feature that is present in both readers and tags, essential for the communication between the two.

Regardless of the communication method used, the range of the wireless link as well as the size of the antenna is related to the frequency of the carrier wave.

Carrier frequencies

Unlike wired communication systems, which can be physically isolated from each other, wireless communication systems must adopt a different approach for preventing interference. In general, RFID system components are separated by carrier frequency allocation. Each country manages frequency allocations within the guidelines set out by their region of the world – Europe and Africa (Region 1), North and South America (Region 2) and Far East and Australasia (Region 3). To date, there is no consistency between regions over the allocation of frequency bands, but many countries are working toward uniformity by the year 2010.

Currently, eight frequency bands are in use around the world ranging from a low 100 kHz to a high of 6.8 GHz. At the low end, less than 135 kHz, a wide range of products are available to suit a variety of applications, including animal tagging, access control and track and traceability. RFID systems that operate in this band are characterized by slow transmission speeds and short communication ranges, but tag cost is usually high because the tags are large, and they can be adversely affected by fluorescent light. In many countries, transponder systems that operate in this band do not need to be licensed.

In the intermediate range – between 10 and 15 MHz – RFID systems have a short communication range, but tag cost is still high because of the large antenna required. RFID systems in this band are susceptible to mutual interference and are easily affected by the presence of metal. A number of EAS systems and industrial, scientific and medical applications have been developed to utilize the 13.56 MHz carrier frequency including access control systems and smart cards.

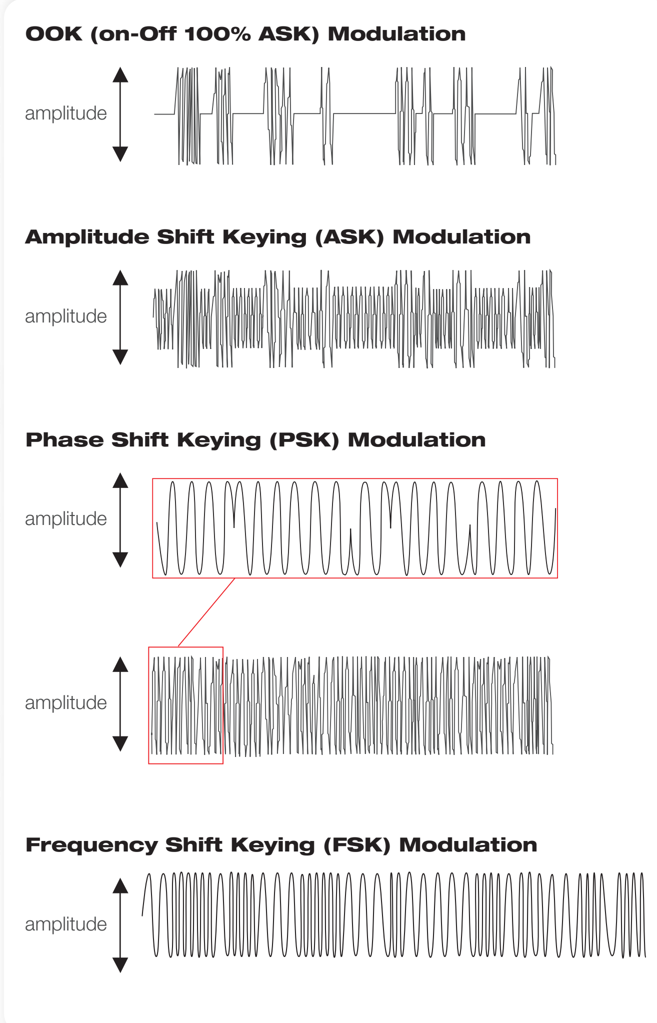
At the high end, a frequency band between 850 and 950 MHz is well organized within Region 2 with many different types of applications with different levels of priorities. In the United States, this includes railcar and toll road applications. The band has been divided into narrow band sources and wide band (spread spectrum type) sources. This band cannot be used in Japan; and in Region 1, the same frequencies are used by the GSM cellular telephone network.

A high-frequency band between 2.35 and 2.45 GHz has been recognized by IEEE 802.11 as suitable for RF communications. Both spread spectrum and narrow band systems are in use in this band. Another high frequency band – between 5.4 and 6.8 GHz – has been allocated for future use. The FCC has been requested to provide a spectrum allocation of 75 MHz in the 5.85-5.925 GHz band for Intelligent Transportation Services use, while in France, the vehicle-to-roadside communications system is based on vehicle communications with the roadside via microwave beacons operating at 5.8 GHz.

The carrier frequency band chosen will determine the data transfer rates that can be achieved. In general, the higher the frequency of the carrier wave, the higher the data transfer rate. To achieve a specific data transfer rate, the channel bandwidth should be at least twice the bit rate required for the application. This can be an important concern in narrow band allocations where the data rate is limited. It is less of an issue for wide band allocations because increasing the bandwidth allows an increase in the noise level and a reduction in signal-to-noise ratio. Since it is generally necessary to ensure a signal is above the noise floor for a given application, bandwidth is an important consideration in this respect.

Modulation

To efficiently transfer data in the air space separating the tag and reader the data is superimposed on a sinusoidal carrier wave within a designated frequency band. This superimposition is typically called modulation. Modulation is performed by changing the value of one of three primary features of the alternating sinusoidal carrier wave – its amplitude, its frequency or its phase. As a result, the three primary modulation schemes are: amplitude shift keying (ASK), frequency shift keying (FSK) and phase shift keying (PSK).



▶ **Figure 2.** *Modulation Methods*

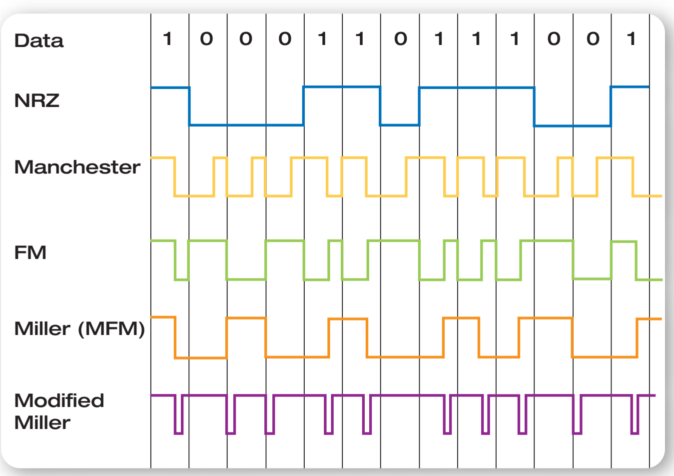
Other methods of modulating include pulse position modulation (PPM), Phase Jitter Modulation (PJM), and pulse duration modulation (PDM). In some cases, different modulating techniques are used in each direction (to and from the tags). Each modulation scheme has attributes that favor its use.

Coding

Noise, interference and distortion can all corrupt transmitted data, making error free data recovery difficult to achieve. This is compounded by the fact that data communication processes are asynchronous or unsynchronized, so care must be taken with the form in which the data is communicated. RFID system manufacturers use channel encoding schemes to structure the bit stream, thus creating the desired communication performance and solving many data corruption problems.

Channel encoding schemes include the following:

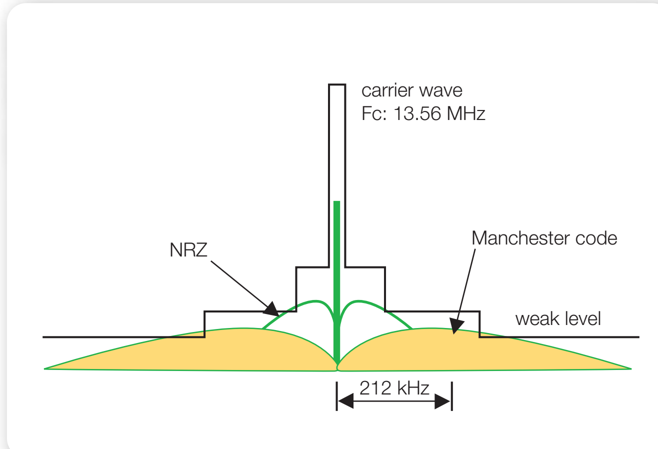
- **NRZ –** A binary 1 is represented by a high signal and a binary zero by a low signal. This coding scheme is often used with FSK or PSK modulation.
- **Manchester (or bi-phase) –** A binary 1 is represented by a negative transition half-way through the clock cycle and binary 0 is represented by a positive transition. This coding scheme is often used in RFID systems employing load modulation using a sub-carrier.
- **FM –** A binary 1 is coded by a transition of any type, a binary 0 is coded by lack of transition.
- **Miller –** A binary 1 is represented by a transition of any type at half-bit period, a binary 0 is represented by the continued level of the previous 1 over the next bit period. A series of zeros causes a transition at the start of the next bit period. Miller is sometimes referred to as "Modified FM" or "MFM" coding.
- **Modified Miller:** Each transition is replaced by a negative pulse. This coding scheme is very useful for inductively coupled RFID systems due to the very short pulse durations. By having tpulse<Tbit, a continuous power supply can be provided to the transponder from the HF field of the reader even during data transfer.



▶ **Figure 3.** *Coding methods*

There are three main considerations involved with coding schemes: 1) the signal spectrum, 2) susceptibility to interference (transmission errors), and 3) power supply interruption.

The spread of the signal spectrum differs with the coding method. For example, Figure 4 shows the difference signal spectrum spread between the NRZ code and Manchester code spectra.



▶ **Figure 4.** *Differences in coding*

Multiplexing and Anti-collision

Reading or transferring data requires a finite period of time, even if only milliseconds. When a large volume of tags must be read together in the same RF field, the application needs multiplexing and anti-collision features that enable the reader to receive data from each tag. Anti-collision is especially important in applications where a large number of tags are packed tightly together – as on store shelves or in inventory applications (warehouses). Anti-collision methods are usually proprietary since there are no established standards for how this function is to be accomplished.

In general, anti-collision functions are built upon three multiplexing technologies: Space Division Multiple Access (SDMA), Frequency Division Multiplexing (FDMA) or Frequency Hopping (FHSS), and Time Division Multiplexing (TDMA). SDMA technologies are limited to frequencies over 850 MHz and are characterized by high cost and complicated circuitry. FDMA or FHSS transponders utilize adjustable frequency techniques to separate frequencies to/from the transponders.

TDMA technology is the most popular multiplexing method for RFID applications and can be either reader-driven (polling and binary search method) or transponder driven (ALOHA).

Communicating between tag and reader

Two things happen when an RFID tag and reader communicate – they share energy and they transfer information. Information transfer can take place on the down link – from the reader to the tag – or on the up link – from the tag to the reader. RFID systems typically utilize one of three communication procedures to perform this energy sharing and information transfer: full duplex (FDX), half duplex (HDX) and sequential (SEQ).

In the full duplex procedure (FDX), the data transfer from tag to reader (uplink) takes place at the same time as the data transfer from reader to tag (down link). In the half duplex procedure (HDX), the data transfer from tag to reader alternates with data transfer from reader to tag. In both cases, the transfer of energy from reader to tag is continuous, independent of the direction of data flow. This includes procedures in which data is transmitted from the transponder at a fraction of the frequency of the reader (i.e. a subharmonic), or at a completely independent (i.e. an anharmonic) frequency.

In sequential systems (SEQ), on the other hand, the transfer of energy from the transponder to the reader takes place for a limited period of time only (pulse operation). Data transfer from the transponder to the reader occurs in the pauses between the power supply to the transponder.

▶ **Figure 5.** *RFID communication procedures*

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