Phase Jitter Modulation (PJM) used by ISO/IEC 18000-3 Mode 2

About PJM

PJM stands for **Phase Jitter Modulation**. This new system is specified in ISO/IEC 18000-3 Mode 2 and provides for very fast data rates that are as much as 100 - 400 times faster than other RFID data rates. In fact the data rate of PJM Mode 2 at 13.56 MHz HF is demonstrably many times faster than the data rates of other HF technologies and indeed UHF technologies.

General Description

Mode 2 uses a method of transmitting data from an interrogator to a tag using small phase shifts of the interrogation field. The PJM signal can be considered as the sum of an unmodulated carrier signal and a data modulated quadrature carrier signal which has been attenuated and filtered. The attenuated quadrature component appears as a tiny phase jitter of the interrogation field. This form of modulation has been termed phase jitter modulation or, for convenience, PJM.

PJM has a number of inherent advantages over the previous PPM method.

1) There is no change in the amplitude of the interrogation field and hence the transmission of power to the tag is unaffected by PJM.
2) Sideband levels are independent of data rate and can be adjusted to suit the regulatory environment.
3) The bandwidth of the PJM signal is no wider than the original modulated data bandwidth allowing the maximum possible data rate to be passed by the interrogator and tag antennas.
4) PJM is amenable to linear filtering techniques and can be:
   a) Pre-compensated to cancel the effect of narrow interrogator or tag antenna bandwidth's
   b) Filtered to eliminate modulation products, out of band emissions and the upper or lower sidebands as required.
5) Where the interrogator removes the upper or lower sidebands for regulatory purposes the missing sideband is automatically regenerated in the tag detection circuits through the mechanism of spectral regrowth.
6) No information is carried in the amplitude of the PJM signal therefore amplitude compression caused by the tag antenna circuits has no effect upon the recovery of PJM data.

Detailed Description

The PJM signal can be considered as the sum of an unmodulated carrier signal and a data modulated quadrature carrier signal, which is attenuated and filtered. The attenuated quadrature component appears as a tiny phase jitter of the interrogation signal.

Figure 1 shows an example PJM waveform where the superimposed sinusoids represent the interrogation field and $2\Delta\theta = +/-\Delta\theta$ the phase jitter caused by PJM.

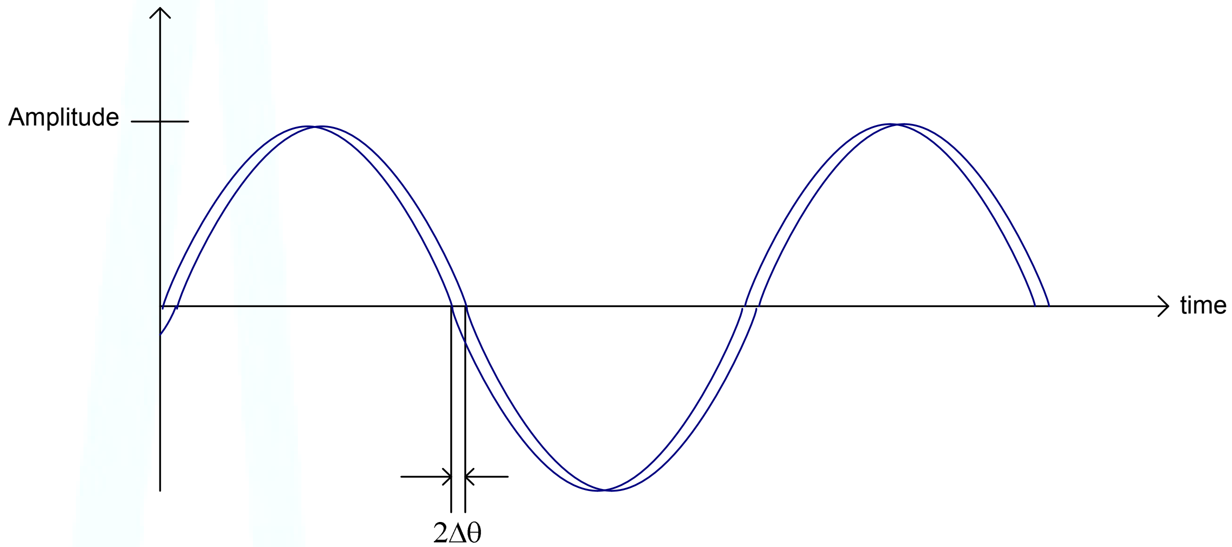

Figure 1: Example PJM waveform

Figure 2 shows a phasor diagram of an example PJM signal such as that shown in Figure 1. The unmodulated carrier is represented by the in-phase vector I and the modulated quadrature signal by the quadrature vector Q. The quadrature vector is PRK modulated which yields the vectors ±Q. The amplitude of the respective signals is given by their phasor lengths.

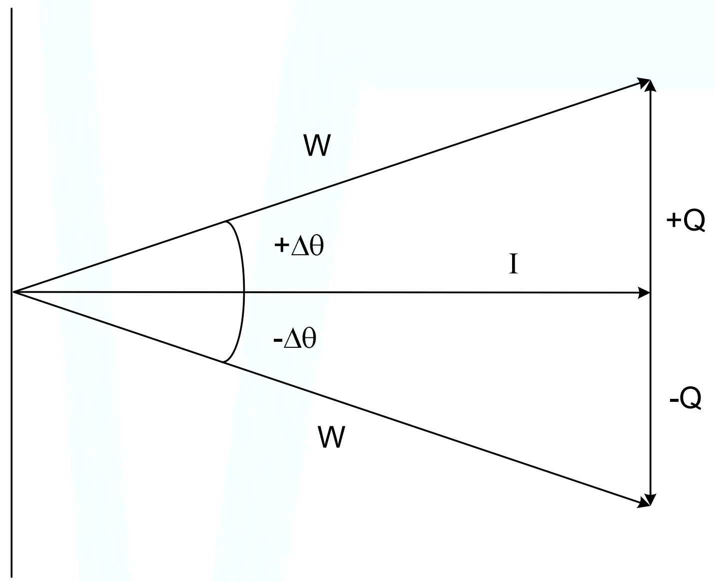

Figure 2: Phasor diagram of example PJM signal

The phase deviation +/-Δθ caused by the modulated quadrature signal is, for low level signals, extremely small and is given by $\Delta\theta = \arctan(Q/I)$. There are many methods of producing small modulated phase shifts, for example, by passing the carrier signal through a phase shifter such as a RC circuit, or through a variable length delay line.

Figure 3 shows an example of a simple RC circuit for providing a data controlled variable phase delay for generating PJM.

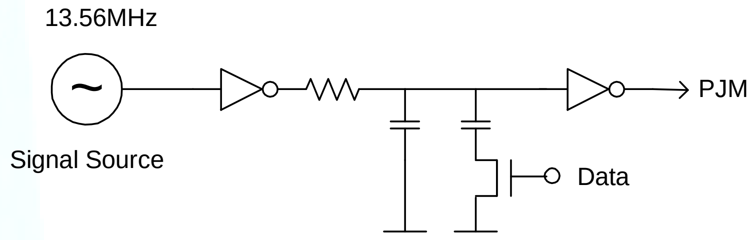

Figure 3: Simple circuit for generating PJM

A more general method of generating PJM, which illustrates the various elements of a PJM signal, is shown in Figure 4. In Figure 4 a small portion of the interrogator's unmodulated carrier signal I is phase shifted 90 degrees to give a quadrature signal Q.
This is then PRK modulated with the data signal, filtered, pre-compensated and attenuated as required. The modulated quadrature signal ±Q is then added back onto the original interrogation signal before being transmitted to the tag.

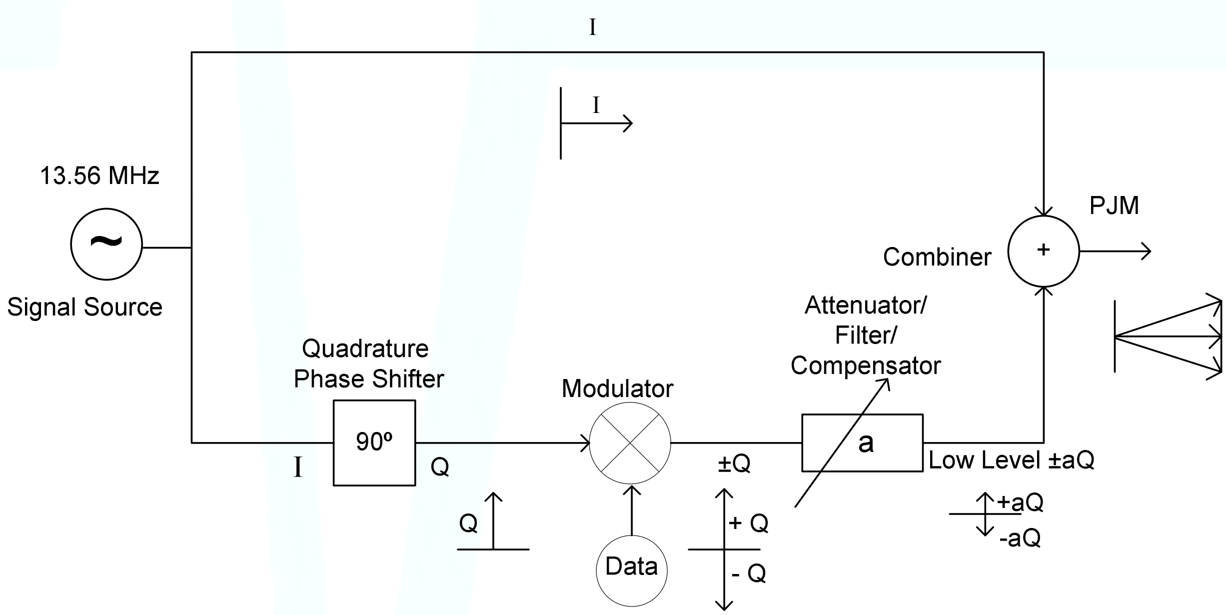

Figure 4: General method for generating PJM

At the tag these tiny phase shifts in the interrogation signal induce corresponding antenna voltage phase shifts that are unaltered by amplitude compression in the power regulation circuitry connected to the tag's antenna. The phase quadrature modulation is recovered using a local oscillator (LO) signal to down convert the modulated data to baseband in a mixer or multiplier. The LO must have a fixed phase with respect to the carrier signal's phase. In the tag the LO signal is derived from the modulated interrogation signal using a low loop bandwidth PLL which locks to the original interrogation signal's phase but is unable to track the high speed modulated phase shifts. The quadrature data signal is down converted and detected in a mixer or multiplier driven with the LO signal.

Figure 5 shows representative frequency spectra for the circuit shown in Figure 4 that explain the method of PJM. The first spectrum is representative of the unmodulated carrier signal I. The second spectrum is representative of the quadrature signal Q when modulated, filtered and attenuated. The third spectrum shows the spectrum of the PJM signal, which consists of the in-phase and modulated quadrature signals summed together. The spectrum of PJM is no wider than the original double sided data spectrum.

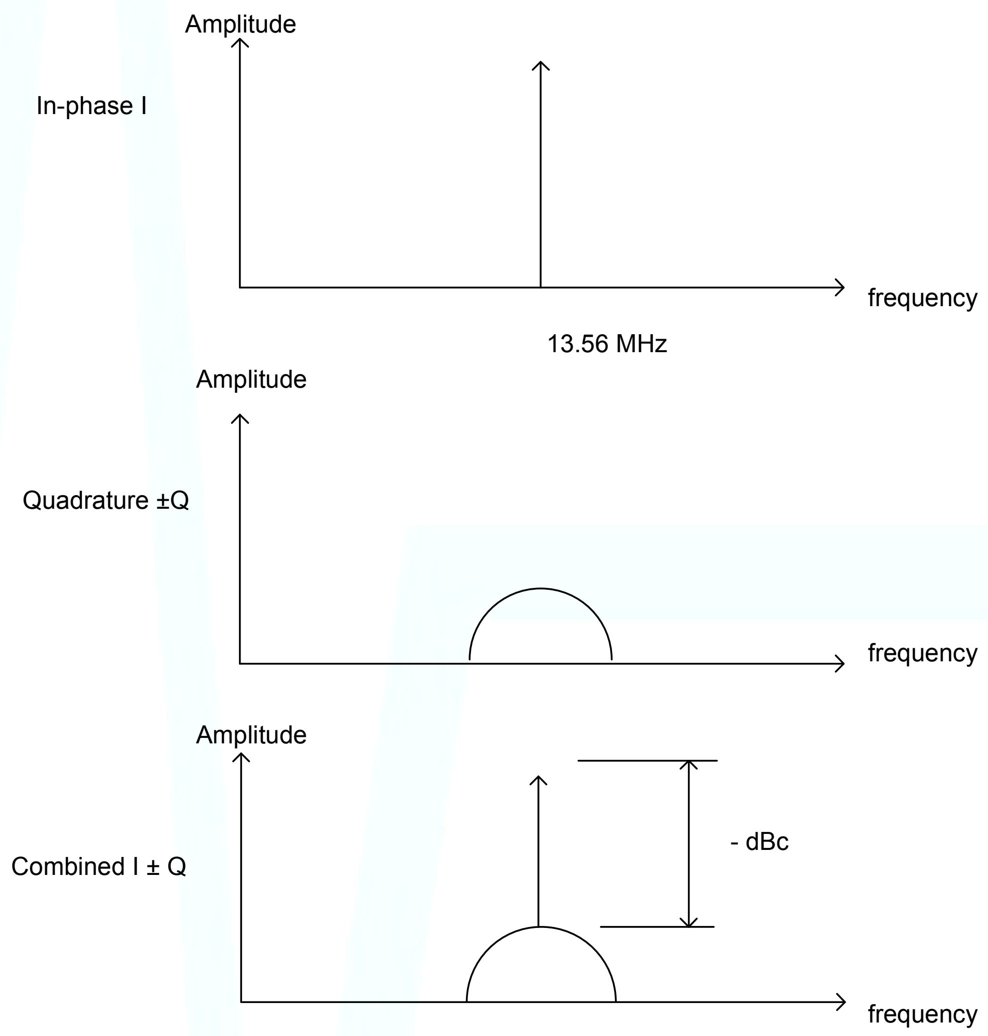

Figure 5: Representative frequency spectra explaining the method of PJM

The sideband levels are given by the difference between the amplitude of the interrogation signal and the amplitude of the data sidebands. For a given phase deviation $+/-\Delta\theta$ the amplitude of the unmodulated quadrature carrier Q in dBc is given by:

$$Q = 20 \log (\tan \Delta\theta)$$

When Q is PRK modulated the resulting upper and lower sidebands of Q are 4 dB lower. If Modified Frequency Modulated MFM encoded data (as defined in Mode 2) is used to PRK modulate Q then the sideband levels are reduced by at least a further 7 dB. The duty cycle of PJM commands to tag replies causes a further reduction in sideband levels. A typical duty cycle is 1:6 which results in a further 7.8 dB reduction in sideband levels.

These figures are given in tabular form in table 1 together with typical figures for a ±1 degree deviation PJM signal.

Parameter	Value	±1 degree example
Deviation	$+/-\Delta\theta$	+/-1
Q	$20 \log (\tan \theta\Delta)$	-35.1 dBc
PRK Sideband	-4 dB	-39.1 dBc
MFM	- 7 dB	-46.1 dBc
Duty Cycle 1:6	-7.8 dB	-53.9 dBc

Table 1: Figures used for calculating sideband levels

Main Features of PJM Technology

Among the more important of the new functionalities provided by Magellan's RFID systems and in particular PJM StackTag® are the following:

High data rate
The speed at which PJM communicates is so fast that it can communicate with many hundreds of tags practically simultaneously. **PJM ItemTag®** and **PJM StackTag®** both have a command data rate of 424 kbits per second. This is very much faster than other technologies. Apart from the major benefit of raw speed this also means that PJM tags can access much more memory in the same time than other RFID tags. Importantly, because of its high speed data rate PJM can also use a full 32 bit CRC (the minimum standard for security) and does not have to fall back on an 8 bit or 16 bit CRC like earlier legacy RFID systems.

Excellent Anti Collision function
Earlier or legacy RFID systems are limited by the fact that the tag and the reader can only communicate on a single RFID frequency or channel. PJM StackTag® and PJM ItemTag® are quite different in that each tag replies on any one or more of 8 different reply frequencies (channels), so where one channel is blocked, for whatever reason, there are seven other channels a tag can use to reply. All replies are at 106 kbits a second but, as these are over eight different reply channels, then the effective notional reply rate if all channels are in use is 848 kbits per second.
For each reply tags randomly but deliberately both choose to reply (or not reply) and select a reply channel. This unique method of reply muting and frequency hopping provides the benefits of time division multiplexed operation with the added major advantage of frequency division. Magellan calls this unique and patented feature **Frequency & Time Division Multiple Access (FTDMA).**
This means, particularly when multiple tags are simultaneously within the operating range of a reader, that they will be correctly identified and their several identifying messages individually and correctly received. Earlier RFID systems cannot do this as they have to use a slot protocol to achieve multiple read. Using slot protocols for anti collision means these systems are both slow and limited in the number of separate tags they can read in the same time.

Un-tuned antenna
PJM ItemTag® is designed primarily, as are all other RFID tags today, to read tags where the individual tags use tuned coils and are well separated from each other. Such tags cannot be read when the

antennas overlap as tuned antennas typically interfere with each other to the extent that none of the touching tags can be read. PJM StackTag® is designed, uniquely, to read multiple tags which touch or are in a stack of some form. Stackable technology is essential in all RFID applications where there is a chance that tags will touch and interfere with each other. PJM StackTags® are made intentionally with un-tuned antennas. This is to ensure that the antenna of tags which touch or overlap do not interfere and either, both or many tags can be read at the same time even when touching or stacked in stacks of 25-40 tags high e.g. in gaming applications or 100 high e.g. in document and jewellery applications.

High and low power mode

PJM StackTags® operate in two power states, a normal power state and a low power state where the tags draw only the lowest possible current. Tags move randomly but deliberately between the normal and low power states so that at any time the majority of the tags are in the low power state. This further eliminates the normal problems associated with parasitic coupling between the antennas of closely stacked tags and also provides the benefits of time division multiplexed operation.

Memory Capacity

Because of the very high data rate, PJM tags have a significant speed/time advantage over other slower tags. This speed advantage translates directly into not only improved communication, and improved anti collision but also into much larger on chip memory. PJM has, for example, the speed to use a 10 kbit memory where other earlier technologies are limited to 256 bits or 512 bits because they simply cannot communicate with or use more memory in the time made available by their slow anti collision systems and slow data rates.

About Magellan Technology

Founded in 1985, and based in Sydney, Australia, Magellan Technology is an RFID technology company providing world class leading RFID solutions based on its unique, patented **PJM** technology which is a super fast High Frequency (13.56MHz) technology. Magellan develops **PJM** chips, tags, readers and operating software.

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