Texas Instruments Registration and Identification System

TIRIS Technology by Texas Instruments™

Wedge Transponder (Pulsed FM)

RI-TRP-R9WK
RI-TRP-W9WK

Reference Manual

11-09-21-024 15 April 1998

Edition Notice: **Third Edition - April 1998**

This is a the third edition of this manual, it describes the following transponders:

RI-TRP-R9WK
RI-TRP-W9WK

This Reference Manual is for customers who wish to use the TIRIS Wedge Transponder in Radio Frequency Identification (RFID) installations. The manual includes technical information concerning the function, technical specifications, application and environmental related data.

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1. Introduction

The TIRIS Pulsed FM Transponder in a wedge shape package is a key product in low frequency RFID systems that can be used for a variety of applications, such as automotive security systems.

The device is available in Read Only (RO) and Read/Write (R/W) versions. Electro Magnetic signals are used to power the passive (batteryless) device, to transmit the identification number to a reader unit or to program the device with new data. The basic principle is described in Figure 1.

Both RO and R/W versions use an 80 bit non-volatile memory (EEPROM) for storage of 64 identification bits and a 16 bit Block Check Character (BCC). The RO type is factory programmed with a unique tamperproof code that cannot be altered. The R/W version can be programmed by the user.

The Wedge Transponder comprises a ferrite core antenna, a charge capacitor and the integrated circuit (Figure 2). The antenna inductance and an on-chip capacitor form a high quality resonant circuit. The components are enclosed in a plastic housing.

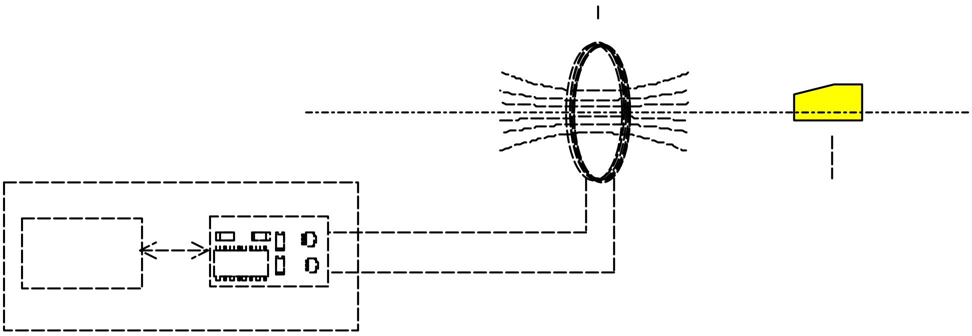


Figure 1: System Configuration Showing the Reader, Antenna and Transponder

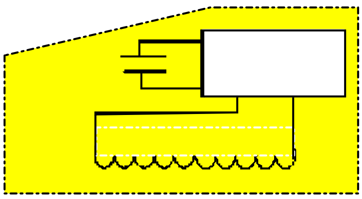


Figure 2: Block Diagram of the TIRIS Pulsed FM Transponder

2. Transponder Packaging

The dimensions of the transponder are given in Figure 3. The transponder housing material is IC mold compound. Notches allow the fixation of clips to assist in mounting or the addition of second packaging.

The wedge shape offers several advantages:

1. It minimizes the total size of the transponder for easy integration into secondary packages.
2. It provides a physical indication of the orientation of the antenna within the transponder to ensure correct antenna orientation at integration.
3. It supports the ability to randomly pack transponders for the shipping process, thus reducing overall costs.

Figure 3 shows the dimensions of the transponder and the orientation of the antenna axis to ensure optimal coupling to the transmit/receive antenna of the transceiver unit.

3. Product Codes

64 bit Read Only device: **RI-TRP-R9WK**
64 bit Read/Write device: **RI-TRP-W9WK**

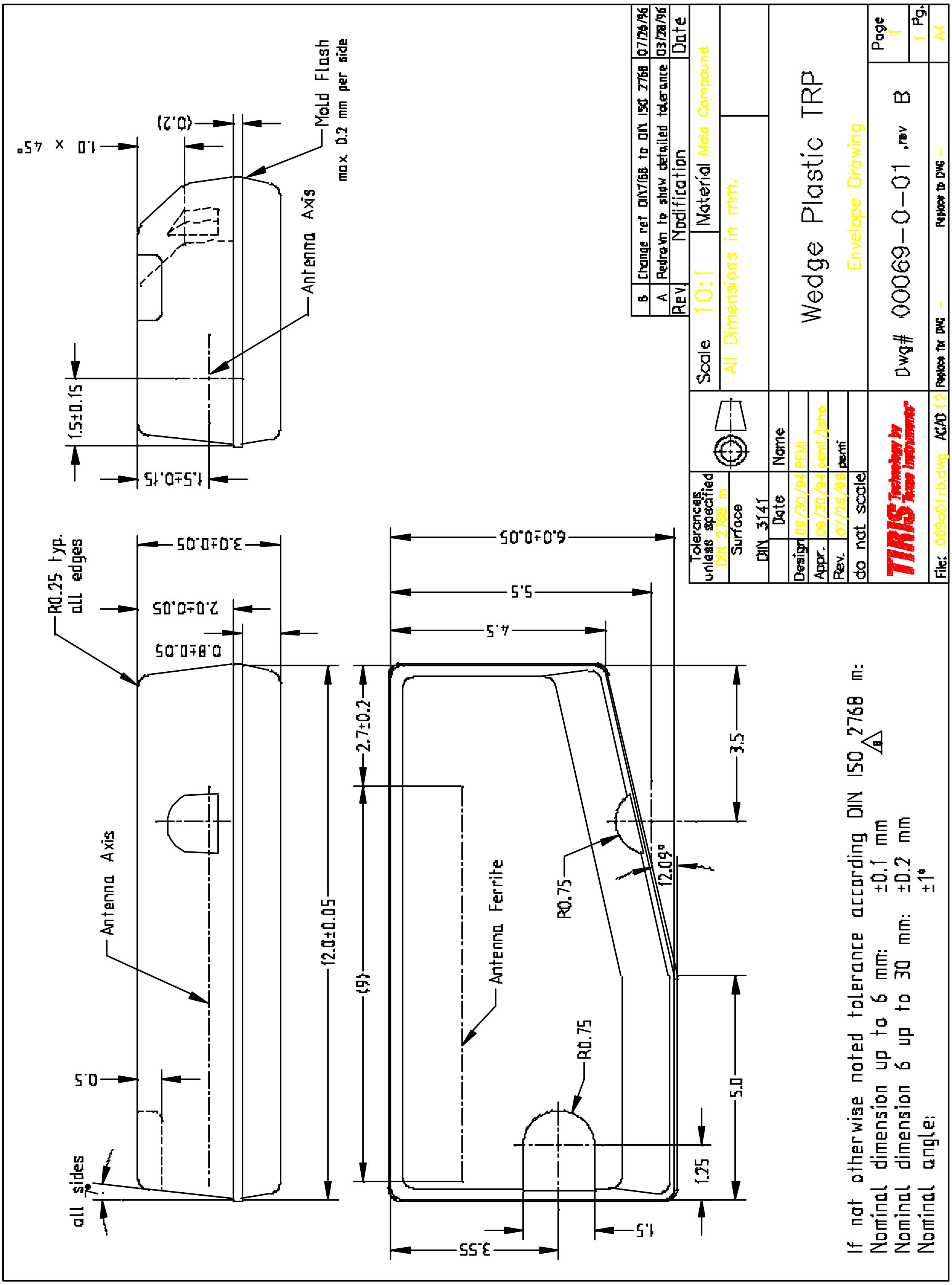


Figure 3: Dimensions of the TIRIS Wedge Transponder (in mm)

4. Function

The Pulsed FM System uses a sequential function principle separating the transponder powering (charge) and transponder data transmission mode. The advantages of the sequential mode are described in Section 5.1 "Basic System Data".

4.1 Read (Reading of RO and R/W Transponders)

During the charge (or powering phase) of between 15 and 50 ms the interrogator generates an electromagnetic field using a frequency of 134.2 kHz. The resonant circuit of the transponder is energized and the induced voltage is rectified by the integrated circuit to charge the capacitor. The transponder detects the end of the charge burst and transmits its data using Frequency Shift Keying (FSK), utilizing the energy stored in the capacitor.

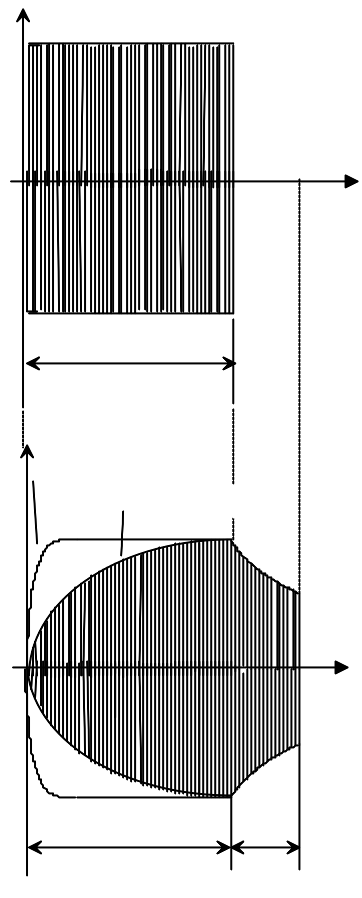


Figure 4: Charge and Read Function of the Transponder, Showing the Voltage at the Transponder and Exciter (Reader) Coil

The typical data low bit frequency is 134.7 kHz, the typical data high bit frequency is 123.7 kHz. The low and high bits have different durations, because each bit takes 16 RF cycles to transmit. The high bit has a typical duration of 129.3 µs, the low bit of 118.8 µs. Figure 5 shows FM principle used. Regardless of the number of low and high bits, the transponder response duration is always less than 20 ms.

The data format consists of 128 bits. Different start/stop bytes and end bits are used, to allow secure distinction between RO and R/W Transponder. Figures 6a and 6b show the format of the received data for RO and R/W transponders.

After transmission of the data format the capacitor is discharged. The typical transponder readout timing is described in figure 4. The charge phase is followed directly by the read phase (RO mode).

Data encoding is done in NRZ mode (Non Return to Zero). The clock is derived from the RF carrier by a divide-by-16 function.

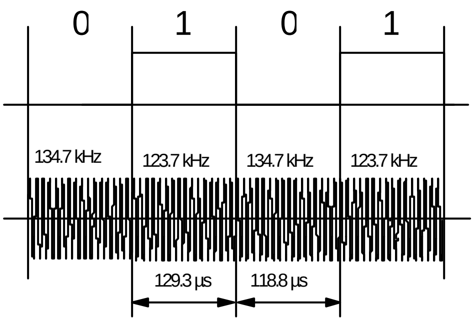


Figure 5: FM Principle Used for the Read Function of TIRIS Transponders

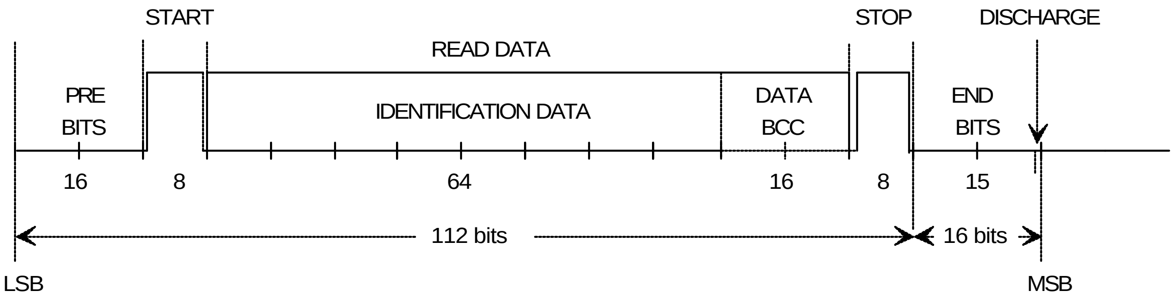


Figure 6a: Read Data Format of TIRIS RO Transponder

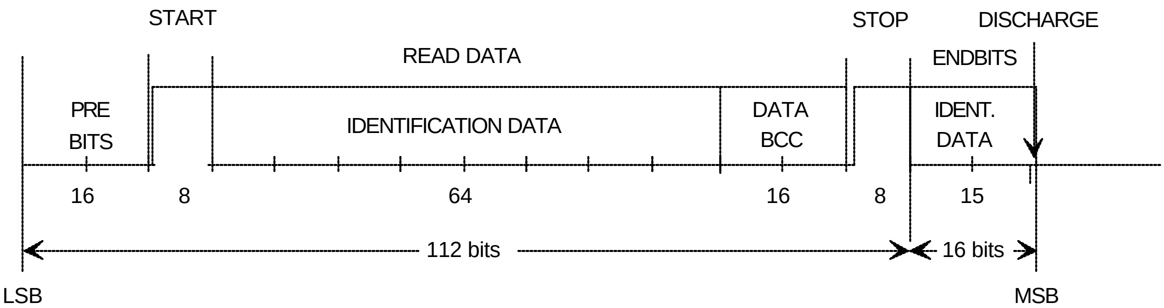
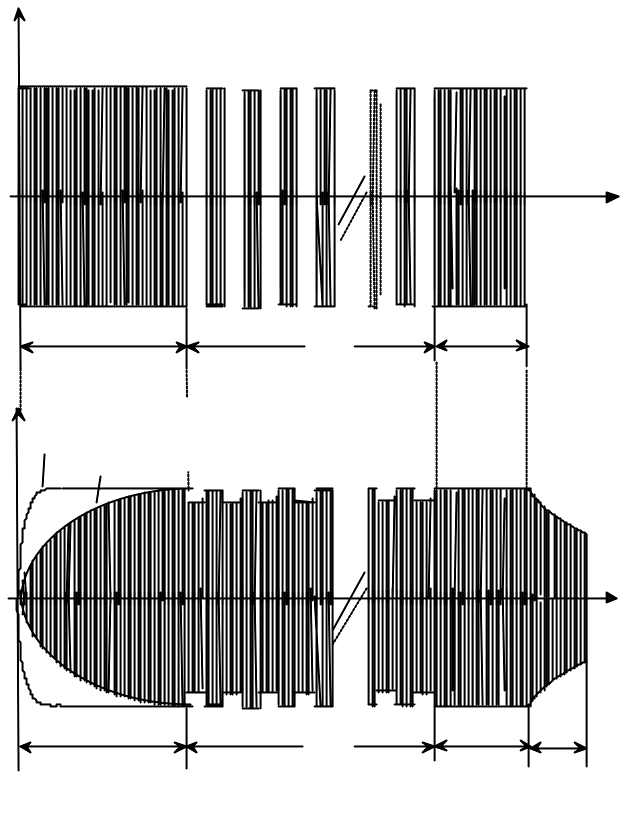


Figure 6b: Read Data Format of TIRIS R/W Transponder

4.2 Write and Program

A new identification number can be written (programmed) into a R/W transponders in the following manner: After the charge phase the R/W transponder enters the write mode providing the reader starts to modulate the field by switching the transmitter on and off (TXCT-). Modulation index of this amplitude modulation is 100%. The duration of the off-phase defines whether a low bit or a high bit is being transmitted (Pulse Width Modulation). Writing means, the transponder shifts the received bits into a shift register. After the write phase the reader's transmitter is switched on for a certain time (programming time) in order to energize the process of programming the shift register data into the EEPROM. All 80 bits are programmed simultaneously into the EEPROM. Once the data is programmed into the EEPROM the transponder automatically sends back the captured data to the reader to allow a security check, this process takes place when the transmitter is switched off. Each read unit can be used as a write unit through software change only. No hardware changes are required.

Figure 7 describes the write function by showing the transmitter (reader) RF output signal and the transponder RF input signal. Figure 8 shows the TXCT- signal of the reader (transmitter) during the write and program function. The data transmission format of the write mode is described in figure 9.



Charge:	Continuous RF Module transmitter output signal
Write:	Pulse width modulation of the RF module transmitter output signal
Program:	Continuous RF module transmitter output signal
Read:	Frequency Shift Keying of the transponder resonant circuit oscillation

Figure 7: Charge, Write and Program Principle used for TIRIS, showing the voltage at the exciter (reader) and transponder antenna coil

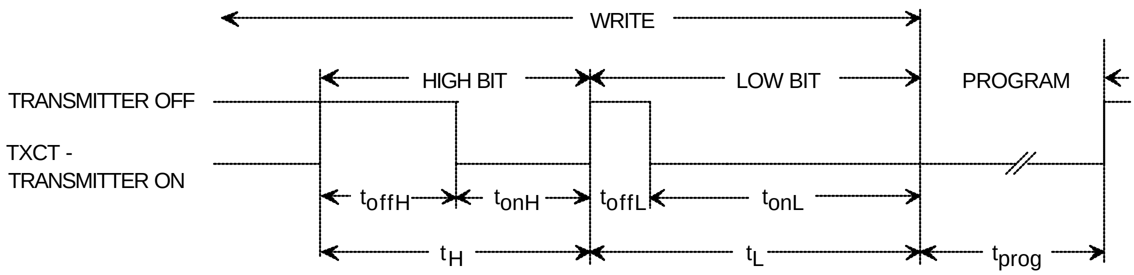


Figure 8: The Write and Program Function

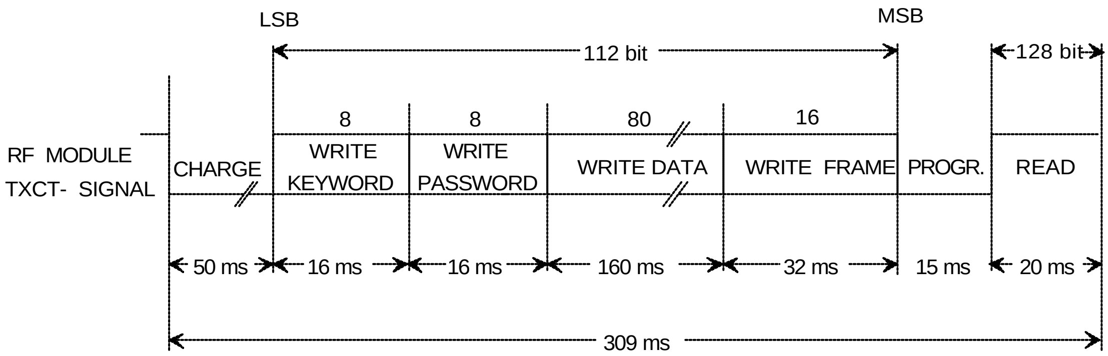


Figure 9: Write Data Format for Programming Function

5. Characteristics of the Pulsed FM System

5.1 Basic System Data

The TIRIS Pulsed FM system multiplexes the power and read functions avoiding compromises. This results in the following characteristics and options:

a) Individual optimization of the power and read functions by the system designer.

b) Variation of powering time by S/W to trade-off speed/current consumption with other parameters

c) Absence of the high powering signal during the data reception phase

d) Data transmission by an active oscillator. This is associated with a high signal strength level and a high transponder efficiency.

e) Transponder has an on-chip resonance capacitor.

f) NRZ modulation encoding for high data speed and low transmission bandwidth.

5.2 Reader and System Design Impact

* Ease of receiver and power function design and the optimization of performance due to sequential power/read functions.

* Low field strength for transponder charge, resulting in lower cost of the power function.

* Optional performance and cost trade-offs by variation of:

  interrogation speed by S/W down to 35 ms.
  component selection to achieve different EMI performance levels.

5.3 System Performance and Functional Reliability Impact

* Inherent EMI robustness and high system Signal/Noise ratio because:

  A. The transponder emits 6..20 dB higher data signal (compared to conventional systems).

  B. The powering phase is noise immune and the data transmission phase duration is typically 16 ms.

  C. FSK and NRZ allow a high data rate (typically 9 kbit/s).

  D. Modulation is direct carrier FSK which has inherent AM noise suppression.

* Low reader power dissipation because of low charge field strength.

* Low power consumption due to pulsed operation (=low peak power x low duty cycle).

* Data telegram transmission is secured by 16 bit CRC-CCITT error detection protocol.

* The receive time is short, because the transponder protocol always starts at the beginning of the data stream. Therefore read repetitions are not necessary.

5.4 Other Quality Factors of the TIRIS Pulsed FM System

* High and consistent transponder product quality and performance.

* The direct FSK provides enhanced separation and better position-selective reading of adjacent transponders compared to AM systems.

* Product migration path concept from RO to R/W to Password protected and Multipage transponders. The reader or system can be changed from RO to R/W by S/W change only.

* TIRIS transponders are 100% tested according to the procedures of TI's Total Quality Culture.

* The reliability of TIRIS transponders is monitored through the following tests: temperature and humidity, thermal shock, and operating life.

6. EMI/EMC Performance

6.1 General

For any given RF-ID system, the EMI/EMC performance is determined by three factors:

1. The reader design and the resulting noise immunity performance
2. The signal strength of the transponder and Signal/Noise ratio at the receiver input
3. The transponder immunity to EM fields:
   - The most critical EMI factor or component in a system is the reader immunity.
   - A high transponder data signal facilitates reader design through the higher Signal/Noise ratio.
   - The least critical component is the transponder. Immunity levels are generally very high.

All EMI sources can be classified into three different categories:

a. Broad band "industrial" noise of sporadic or continuous nature
b. Discrete radio frequency signals unmodulated or FM /FSK modulated
c. Discrete radio frequency signals which are AM or ASK modulated.

6.2 The Automotive Environment and Factors

In an automotive environment all noise types are present and potentially cause EMI problems.

Especially the increased application of electronics and communication systems in cars employing digital and ASK type modulation techniques can produce and emit high field strength levels.

The highest energy noise sources are in the low frequency part of the spectrum at frequencies from a few cycles up to a few kHz. The sources are actuators, solenoid switching, ignition, motors, control circuitry and so on. They pollute the car environment, either by direct emission, or by induction, or by conducted radiation.

Above 10 kHz, the noise levels decay quickly at a rate of 20...40 dB/octave. RFID systems emitting and receiving data signals at these or higher frequencies are less affected by EMI.

6.3 TIRIS Pulsed FM Transponder and System Performance

EMI measurement procedures which are most currently cited (for example the DIN 40839/part4) are inappropriate to:

a. determine a realistic RF-ID *system behavior* for an automotive environment
b. determine the EMI performance and threshold of transponder
c. test systems at worst case (low frequency) conditions.

However the TIRIS transponder meets and exceeds the DIN40839/part4.

The TIRIS system performance using reader and wedge transponder is shown in figures 10, 11 and 12.

Figure 10 shows the system immunity over a spectrum of 6 decades. At the most critical Radio Short Wave Broadcast frequencies 400 V/m were encountered.

Figure 11 highlights the system performance simulating in-car RF communication conditions.

Figure 12 shows the performance (reading range) under induced broad band noise (white noise) conditions.

Pulsed FM EMI System Performance

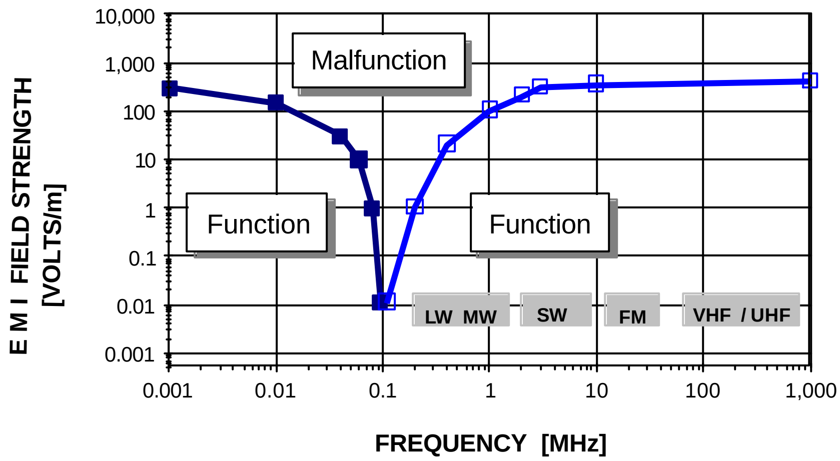


Figure 10: EMI Performance Test of the TIRIS System.

The graph shows the EM Immunity level in V/m as function of the frequency range from 1 kHz to 1000 MHz. Measurement condition: minimum 90% read probability at maximum read range. Using a standard TIRIS reader.

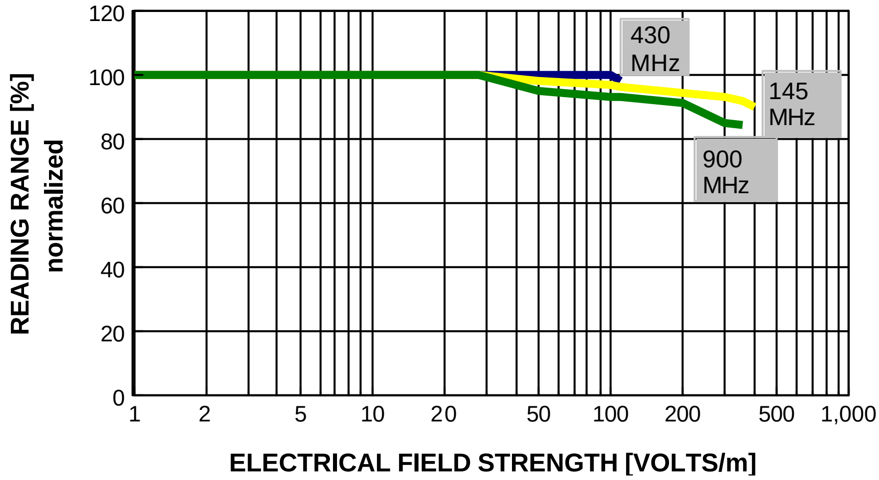


Figure 11: EMI performance at commonly used radio communication frequencies in automotive environment.

White noise performance of TIRIS

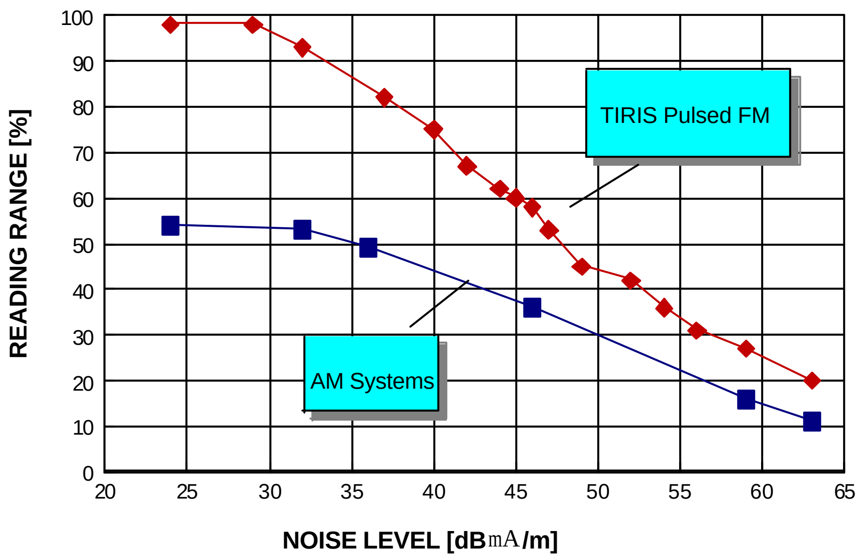


Figure 12: Reading range under broad band noise (white noise) conditions

7. Measurement Set-Ups

This Section describes typical measurement set-ups to determine transponder relevant data like: resonant frequency, bandwidth, quality factor, powering field strength and transponder signal field strength as listed in Section 9 "Recommended Operating Conditions".

7.1 Measurement Set-Up: Resonance frequency, bandwidth, quality factor of transponder

This test set-up is suitable for resonant frequency (f_{res}) measurements as well as the determination of the -3dB bandwidth (Δf) of the transponder. The quality factor Q of the transponder resonance circuit can be calculated with equation (1):

(1) $$Q = \frac{f_{res}}{\Delta f}$$

The wires of the pick-up coil should be very thin to avoid influence on the measurement results (for example: by damping). The choice of a 1 MΩ input resistor at the spectrum analyzer is recommended. Figure 13 shows the test set-up. The relation between pick-up coil voltage and frequency is shown in Figure 14.

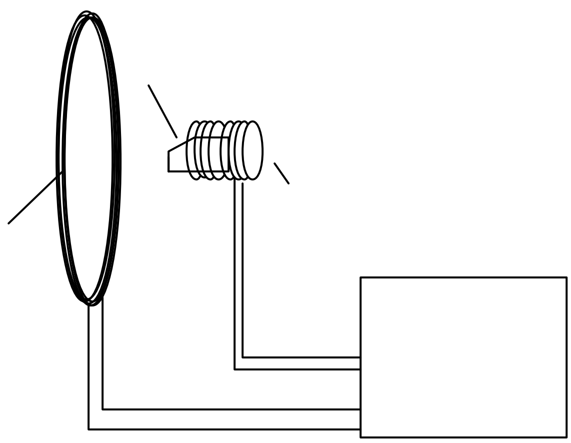


Figure 13: Measurement set-up for the determination of transponder resonance frequency, bandwidth and quality factor

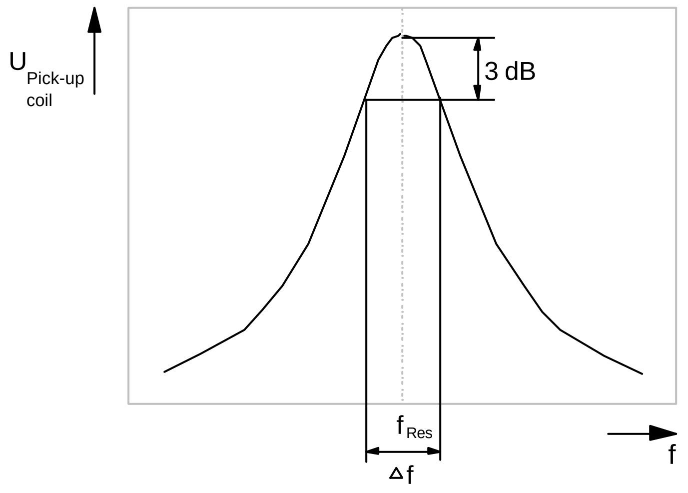


Figure 14: Determination of the resonance frequency and -3dB bandwidth by monitoring the pick-up coil voltage

7.2 Measurement Set-Up: Powering Field Strength

The following set-up is used to determine the minimum required powering field strength.

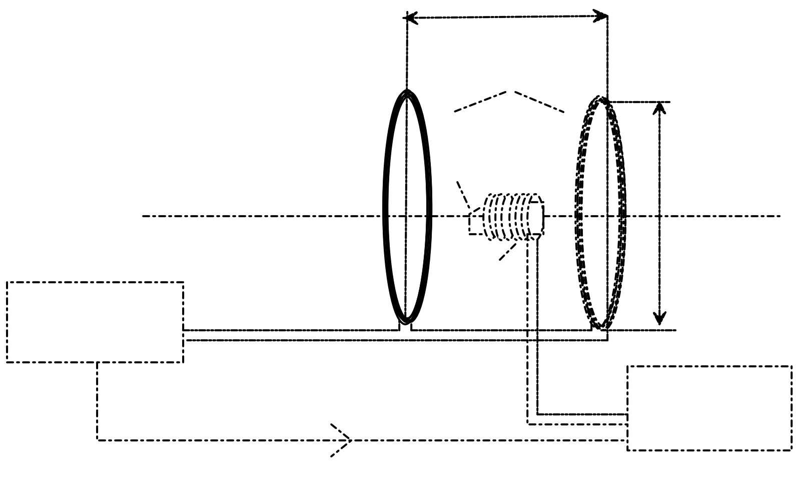


Figure 15: Test set-up for powering field strength determination

The field between both serial connected coils is homogeneous, due to the fact that the aperture is built according to the Helmholtz set-up. The circular coils are positioned in parallel on one axis. The distance between the coils is half the coil diameter. The transponder is positioned in the middle of the coil axis.

Determination of the minimum powering field strength is possible by changing the field strength through increasing the coil current. The relation between the generated magnetic flux / field strength and coil current can either be measured with a calibrated field probe, or calculated as follows:

$$B = \frac{4}{5} \cdot \sqrt{\frac{4}{5}} \cdot \frac{m_o \cdot m_r \cdot N \cdot I}{d / 2} = m_0 \cdot m_r \cdot H \qquad (2)$$

B: magnetic flux (Tesla=Wb/m2)
H: magnetic field strength (A/m)
N: Number of Helmholtz Coil windings
d: Coil diameter (m)
I: Coil current (A)
μ_o: magnetic field constant (Vs/Am) = 4×p×10 $^{-7}$ Vs/Am
μ_r: relative magnetic field constant (in air: =1)

The Helmholtz set-up can be used for the specification of transponders in the temperature range from -40 to +85 ºC. Tests showed, however, that deviations of the field strength caused by temperature are negligible.

The data telegram of the transponder can be captured by a pick-up coil (for example: 10 windings, thin wire to minimize influence) which wraps the transponder. The pulse modulated signal can be adjusted at the signal generator. The measurement of the power pulse and transponder diagram can be done with the help of an oscilloscope triggered by the generator signal (see Figure 15). As soon as a data telegram is completely detected the minimum necessary field strength (calculated with equation 2) can be monitored.

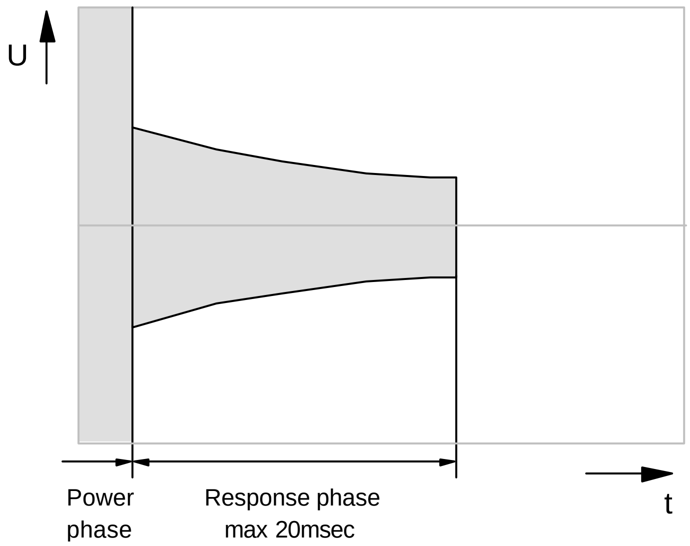


Figure 16: Received signal at the pick up coil, if power field strength is sufficient

7.3 Measurement Set-Up: Transponder Signal Strength

The wedge transponder has to be located into a homogeneous field (Helmholtz set-up). The pulsed power signal is generated by a signal generator. A calibrated field strength probe picks up the transponder signal. The field strength can be calculated by using the calibration factor of the field strength probe.

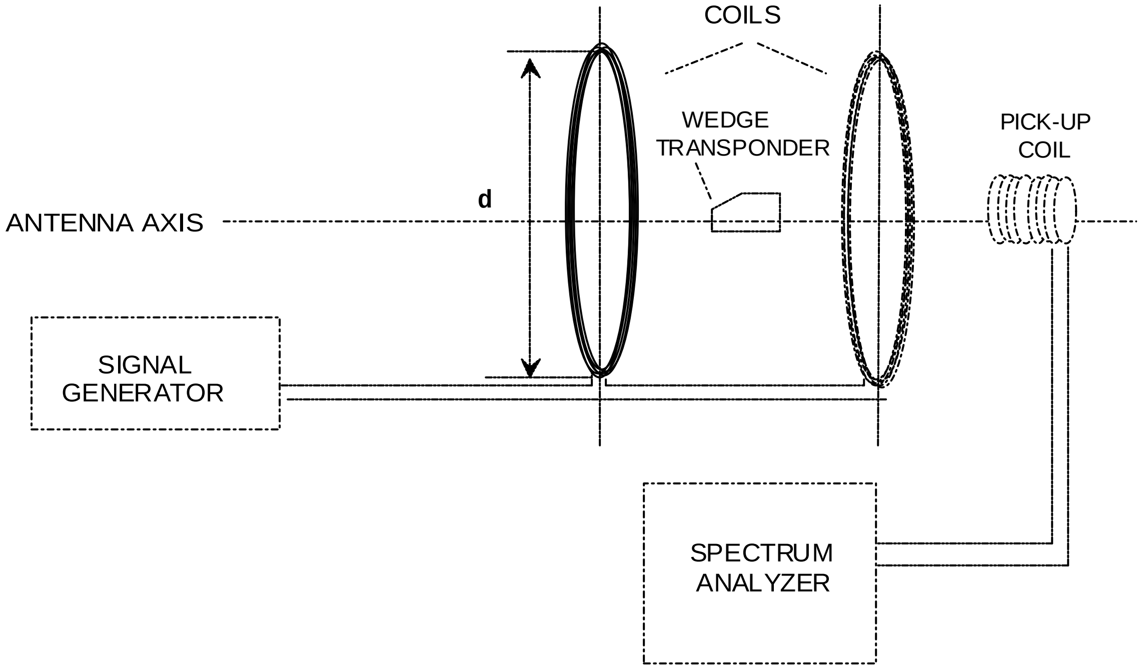


Figure 17: Determination of the transponder signal strength (data transmission signal strength) with Helmholtz aperture

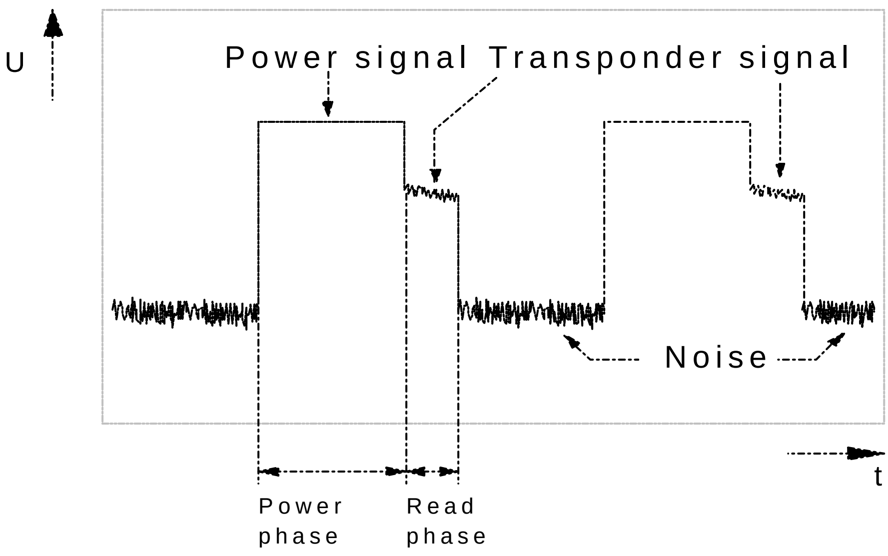


Figure 18: Monitored signal voltage at the spectrum analyzer (time domain mode)

8. Absolute Maximum Ratings

All data given for free air operating temperature range (unless otherwise noted).

PARAMETER		CONDITION	MIN.	NOM.	MAX.	UNIT
Operating temperature (read)	Ta_{read}		-40		85	^oC
Operating temperature (program)	Ta_{Prog}		-40		70	^oC
Storage temperature	T_S		-40		100	^oC
Storage temperature	T_S	5 min			175	^oC
Temperature Cycle	T_C		-40		85	^oC
Field strength	H_{exc}	134.2 kHz			168	dBµA /m

9. Recommended Operating Conditions

All data given for free air operating temperature range (unless otherwise noted).

PARAMETER		CONDITION	MIN.	NOM.	MAX.	UNIT
Charge duration for read and write	t_{exc}		15	50		ms
Charge frequency for read and write	f_{exc}		134.16	134.2	134.24	kHz
Programming time	t_{prog}		15			ms
Programming field strength	H_{prog}	t_{exc} = 50 ms		145		dBµA/m
Programming field strength	H_{prog}	+ 25 ^oC t_{exc} = 50 ms		140		dBµA/m
Activation field strength	H_{act}	t_{exc} = 50 ms	137.5			dBµA/m
Activation field strength	H_{act}	+ 25 ^oC t_{exc} = 50 ms	134.5			dBµA/m
Write bit duration	t_{bit}	*Note		2		ms
Write pulse pause low bit	$t_{off\ L}$	*Note		0.3		ms
Write pulse pause high bit	$t_{off\ H}$	*Note		1.0		ms

Note: *Depending on reader characteristics and environmental conditions.*

10. Characteristics

All data given for free air temperature range (unless otherwise noted).

PARAMETER		CONDITION	MIN.	NOM.	MAX.	UNIT
Operating quality factor	Qop	Note 1	62			
Low bit transmit frequency	f_L		130.2		139.5	kHz
Low bit transmit frequency	f_L	+ 25 °C	132.0	134.7	136.5	kHz
Low bit duration	t_L		0.115	0.119	0.123	ms
High bit transmit frequency	f_H		118.0		128.0	kHz
High bit transmit frequency	f_H	+ 25 °C	120.0	123.7	126.5	kHz
High bit duration	t_H		0.125	0.129	0.136	ms
Transponder output field strength @ 5 cm	H_{out}		76		99.5	dBµA/m
FSK Modulation index (read); f_L - f_H	m_{read}	+ 25 °C		11		kHz
FSK Modulation index (read); f_L - f_H	m_{read}	Note 2	9		15	kHz
Data transmission rate (read)	r_{read}		7.4		8.7	kbit/s
Data transmission time (read)	t_{read}		14.7		17.5	ms
ASK modulation index (write)	m_{write}			100		%
Data transmission rate (write)	r_{write}	Note 3		0.5		kbit/s
Data transmission time (write)	t_{write}	Note 3		224		ms

Note 1: *Specified Qop must be met in the application over the required temperature range. Refer to the test set-up shown in figure 13.*

Note 2: *Maintained over specified temperature range.*

Note 3: *Adaptable to application.*

11. Environmental Data and Reliability

PARAMETER		CONDITIONS	MIN.	NOM.	MAX.	UNIT
Programming cycles	Note 1	25 ^{o}C	100 k			cycles
Data retention time	Note 1	100k cycles @ 25^{o}C storage temperature	10			years
EM Radiation immunity		1...512 MHz	100			V/m
EM Radiation immunity		512..1000MHz	50			V/m
ESD Immunity	IEC 801-2		2			kV
X-ray dose					2000	RAD
Vibration (Note 2)	IEC 68-2-6, Test Fc					
Shock	IEC 68-2-27, Test Ea					

Note 1: *Cumulative failure rate 1%.*

Note 2: *f = 10 - 2000 Hz.*

12. Memory

PARAMETER	DATA
Memory size	80 bits
Memory organization	1 block
Identification data	64 bit
Error detection (Data BCC)	CRC - CCITT , 16 bit

13. Package

PARAMETER	DATA
Dimensions	12 mm x 6 mm x 3 mm (see figure 3)
Weight	0.4 g

Appendix A: Conversion Formula

Conversion formula between magnetic flux, magnetic field strength and electric field strength.

$$B = m_0 \cdot H$$
$$E = Z_F \cdot H$$

$$\mathrm{H} = \left[\frac{\mathrm{E}}{\mathrm{dB}\mathit{m}\mathrm{V\ /\ m}} - 51.5 \right] \frac{\mathrm{dB}\mathit{m}\mathrm{A}}{\mathrm{m}} \quad ; \quad \lfloor \mathrm{H} \rfloor = \frac{\mathrm{dB}\mathit{m}\mathrm{A}}{\mathrm{m}} \quad ; \quad \lfloor \mathrm{E} \rfloor = \frac{\mathrm{dB}\mathit{m}\mathrm{V}}{\mathrm{m}}$$

B = magnetic flux [Tesla = Wb/m^2 =Vs/m^2]; 1 mWb/m^2 = 0.795 A/m

H = magnetic field strength [A/m or in logarithmic term dBµA/m]

E = electrical field strength [V/m or in logarithmic term dBµV/m]

μ_0 = magnetic field constant = 1.257×10^{-6} Vs/Am

Z_F = free space impedance = 120 π Ω = 377 Ω