Texas Instruments

Antenna

Reference Guide

TIRIS Technology by Texas Instruments™

November 1996

SCBU025

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Third Edition - November 1996

This is the third edition of this guide. It contains the same information as the second edition, except that the appendix containing the antenna specifications has been removed. This information should be obtained from the relevant data sheet.

This guide describes the following antennas:

RI-ANT-G01C
RI-ANT-G02C
RI-ANT-G03C
RI-ANT-S01C

If You Need Assistance

Application Centers are located in Europe, North and South America, the Far East, and Australia to provide direct support. For more information, please contact your nearest TIRIS™ Sales and Application Center. The contact addresses can be found on the TIRIS home page:

http://www.tiris.com

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Introduction

1.1 TIRIS

TIRIS stands for Texas Instruments Registration and Identification System, a Radio Frequency Identification (RFID) system.

The core of the system is a small device called a transponder that can be attached to or embedded in an object. A stationary or handheld reader sends a low frequency signal to the transponder via an antenna. This signal charges up the passive (battery free) transponder in milliseconds. The transponder returns a signal that carries a unique, factory programmed, 64-bit binary code back to the reader.

The system is used to identify and track objects or animals.

1.2 Purpose

This guide includes the most important information needed to select the best antenna for a specific applications, to install it correctly, and to optimize its performance. Although the main focus is on TIRIS standard antennas, the guide also contains some theoretical information to help design custom antennas.

The antennas described in this guide, in combination with the other TIRIS system components, offer you a complete radio frequency identification system.

There are two types of antennas available for use with a stationary TIRIS reader: gate (square or rectangular) antennas and stick (ferrite rod) antennas. These standard antennas come in different sizes for maximum flexibility.

Target audience: This guide is for application center engineers and customers who are actively developing TIRIS RFID applications.

If you have questions, please contact your local TIRIS Application Center (http://www.tiris.com).

1.3 About This Guide

This guide contains the following parts:

Chapter 1:	**Introduction.** A short introduction to TIRIS and a short description of the guide itself.
Chapter 2:	**How the System Works.** A description of how the system works, followed by a series of charts showing the "charge-up" distances for different countries for each of the TIRIS antennas.
Chapter 3:	**Noise Characteristics.** A description of noise and its influence on the TIRIS system.
Chapter 4:	**Antenna Voltage and Field Strength.** A description of the allowed antenna voltages and how to calculate other antenna voltages and what field strengths are generated.
Chapter 5:	**Speed Applications.** A description of how to read moving transponders.
Chapter 6:	**Mechanical Characteristics.** A description of the mechanical characteristics of the antennas and how to mount them.
Appendix A:	**Brief Theory of Magnetic Induction.** A short description of magnetic induction.
Appendix B:	**Theory of Coupled Inductors**
Appendix C:	**Glossary of Terms.** A list of the terms and phrases using in this guide together with a short description of each of them.

How the System Works

2.1 Operating Principle

The antenna has two tasks in the TIRIS system:

1. Send an energizing signal to the transponder.
2. Receive the resulting ID signal from the transponder.

2.2 Charge-Up of the Transponder

When the transponder passes through the magnetic field created by the transmitting antenna, a capacitor in the transponder is charged up to a certain voltage. The energy thus created in the capacitor is used to transmit an ID code back to the readout antenna. For proper functioning, the transponder needs a minimum voltage of 5 V on its capacitor.

Because the charge-up takes place in a fixed time, the magnetic field strength of the charging signal is relevant to the maximum readout range (see Appendix A).

2.3 Transponder Orientation

The 'readout diagram' of a transponder depends on the orientation of the transponder with respect to the reader antenna. The magnetic field lines of the reader antenna must incident (cross) the antenna of the transponder, and vice versa, in order to achieve a proper reception. Figure 2-1 through Figure 2-4 show the affect that orientation has on the readout diagram. They show, respectively, the diagrams for orientations of 0°, 30°, 60°, and 90°.

See Appendix B for an explanation of how these definitions of orientation are derived.

2.4 Differences Between Antennas

The performance of the TIRIS system is influenced by the reader antenna selected. Each antenna has its own specific characteristics.

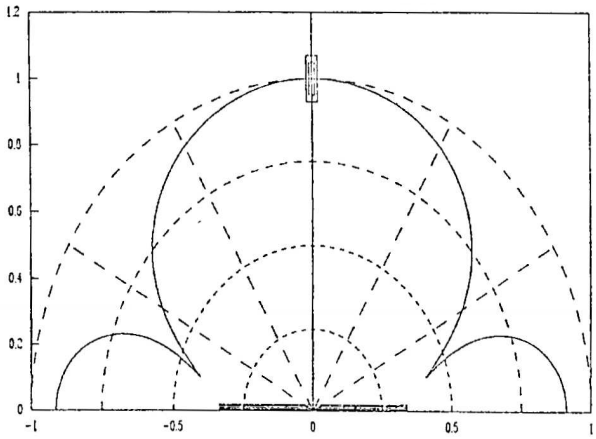


Figure 2-1. 0° Transponder Orientation

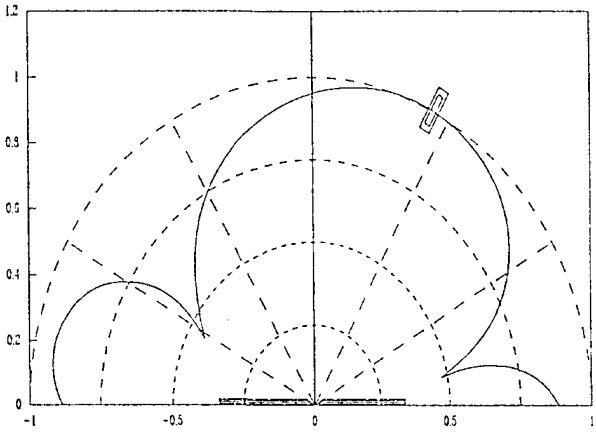


Figure 2-2. 30° Transponder Orientation

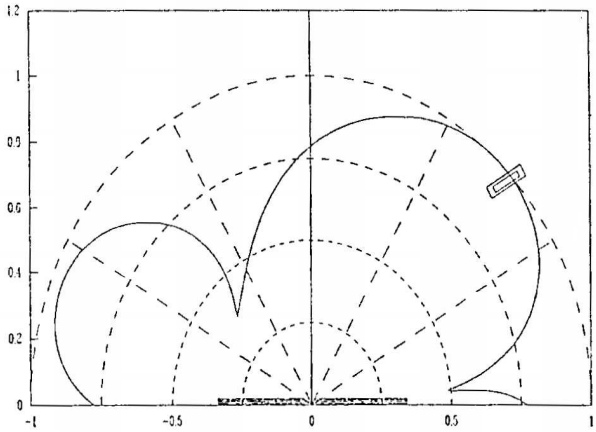


Figure 2-3. 60° Transponder Orientation

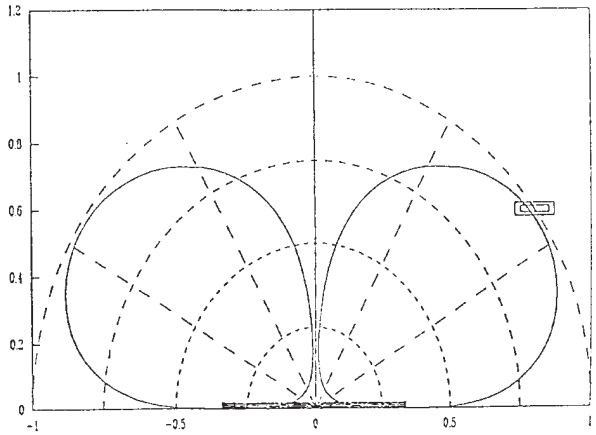


Figure 2-4. 90° Transponder Orientation

2.5 Isofield Diagram

A charge-up (Isofield) diagram shows the field strength achieved by a specific antenna voltage against an axis of length (the distance over which the transponder will be "charged-up" to the required level – the example given in Figure 2-5 is 5 V).

For example: on a G01C antenna, an antenna voltage of 232 V will charge-up a transponder with a 0° orientation to 5 V over a distance of up to 0.68 m.

An 'Isofield' diagram and a charge-up diagram are the same and are independent of noise. A readout diagram includes the effects of noise. Each antenna has its own specific 'Isofield' pattern. The field strength decreases exponentially with the distance to the readout antenna. For short distances this exponent differs for various antennas.

In Figure 2-5 to Figure 2-8 you will see isofield (charge-up) diagrams for the TIRIS antennas. These patterns show you the charge-up of the transponder to 5 V in 50 ms for the 32.5 mm tube transponder. The top diagram on each page is the charge-up diagram with a transponder orientation of 0°, and the bottom diagram on each page is the charge-up diagram with a transponder orientation of 90°. With this charge-up voltage, the transponder is able to reset completely. However, the transponder is able to transmit back its complete ID code with a lower voltage, so the readout distance could be even larger.

Each diagram has several lines or 'envelopes' on it, each representing a different voltage applied to the antenna. The smallest 'envelope' (that closest to the antenna) shows the magnetic field induced by the lowest voltage applied to the antenna, and the largest 'envelope' shows the field induced by the highest antenna voltage (see Table 2-1).

The antenna voltage applied is set according to the regulations of the country in which the system is to be used. Table 2-1 is a table of antenna voltages allowed for each country with a charge-up time of 50 ms and a receive time of 40 ms. By comparing these voltages with the relevant line on the antenna isofield diagram, you can see what the charge-up distance will be for the country that the system will be used in.

Table 2-1. Maximum Antenna Voltages (Peak-to-Peak)(1)

Country	Antenna				Comments
	G01C	G02C	G03C	S01C	
Netherlands	39	98	21	361	CISPR
Germany	43	107	23	393	CISPR
Denmark	43	107	23	393	CISPR
United Kingdom	94	236	51	650(2)(3)	PEAK
Japan	371	713(2)(3)	203	650(2)(3)	PEAK (provisional value only)
United States	499(2)	713(2)(3)	272	650(2)(3)	RMS (100 ms window)
France	688(2)	713(2)(3)	375(2)	650(2)(3)	RMS
Australia	707(2)	713(2)(3)	386(2)	650(2)(3)	PEAK (provisional value only)

(1) The figures given in this table have been agreed with the relevant government agencies and are for "portable equipment". For some countries, (for example, the Netherlands), if the equipment is made a permanent fixture, it is possible to obtain permission for higher antenna voltages to be used.
(2) These voltages cannot be achieved using the RF Module RI-RFM-001. It should be possible to achieve these levels if you use the RF Module RI-RFM-002 which allows approximately twice the antenna voltage of the 001.
(3) Temperature limit of antenna.

2.6 How to Measure Antenna Voltages

The antenna voltages can only be measured using an oscilloscope with a 10 MΩ probe across the antenna terminals (metal-to-metal contact). Check the peak-to-peak level and then reverse the probe contacts and check again; the highest reading is the correct reading.

2.7 How to Use the Charge-Up Diagrams

To work out the charge-up range for a particular antenna, you must first look in Table 2-1 to see what antenna voltage is allowed in the country that the system will be used in. Now go to the charge-up diagram for the antenna, and see where on the diagram (usually between two lines) that value falls. This will show you the readout range (in a environment with an acceptable noise level).

The innermost line (or envelope) shows the reading range possible with the lowest allowed voltage, and the outer line is the range possible with the maximum voltage. On Figure 2-5A, we have marked the voltage value for each line to show how this works.

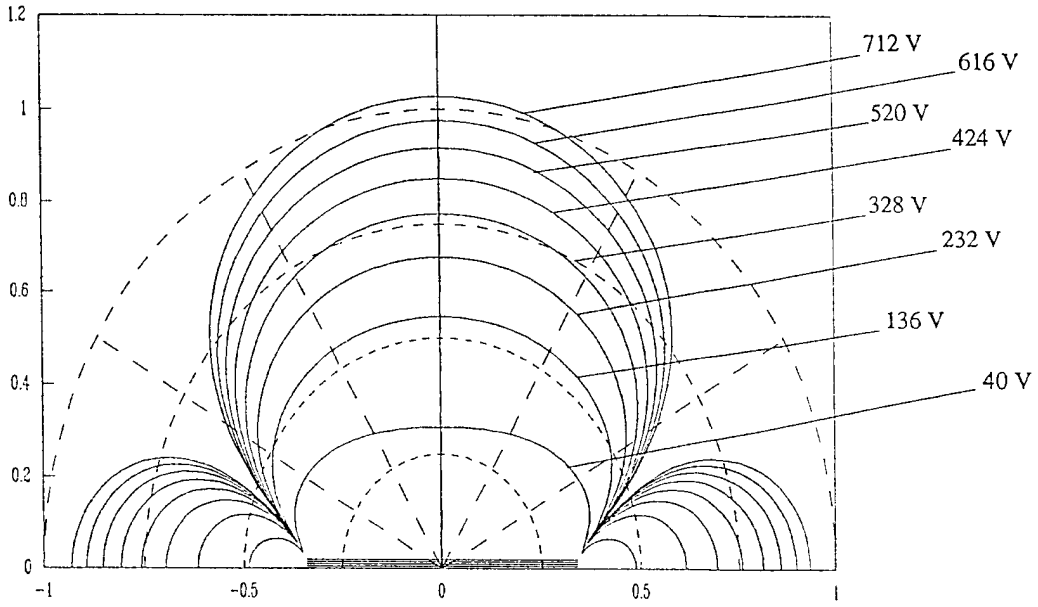
Examples 1 and 2 provide two examples of how to work out the charge-up distance for a particular antenna in two different countries.

Example 1: Using Antenna G02C in Japan

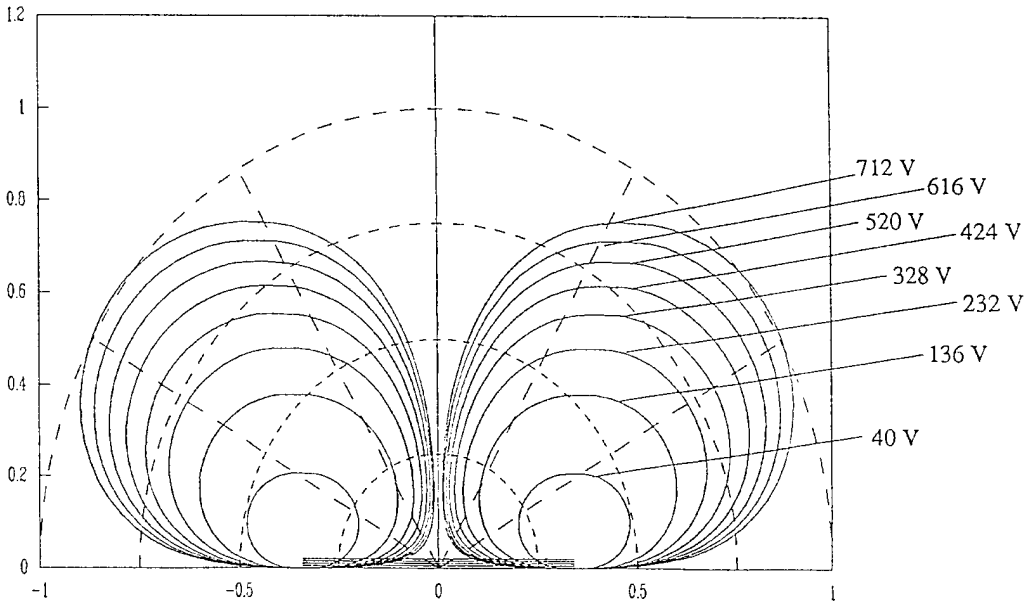
1. Look in Table 2-1, and you will see that the allowed voltage for antenna G02C in Japan is 713 V.
2. Now go to Figure 2-6A. 713 V falls just inside the outer line, which represents 730 V.
3. Using a ruler, line up the 713 V "spot" with the side axis. This shows you that you have a charge-up distance of just over 70 cm (just over 27.5 inches).

Example 2: Using Antenna G02C in Germany

1. Look in Table 2-1, and you will see that the allowed voltage for antenna G02C in Germany is 107 V.
2. Now go to Figure 2-6A. 107 V falls just above the first (inner) line which represents 100 V.
3. Using a ruler line up the 107 V "spot" with the side axis. This shows you that you have a charge-up distance of just under 40 cm (just under 16 inches).

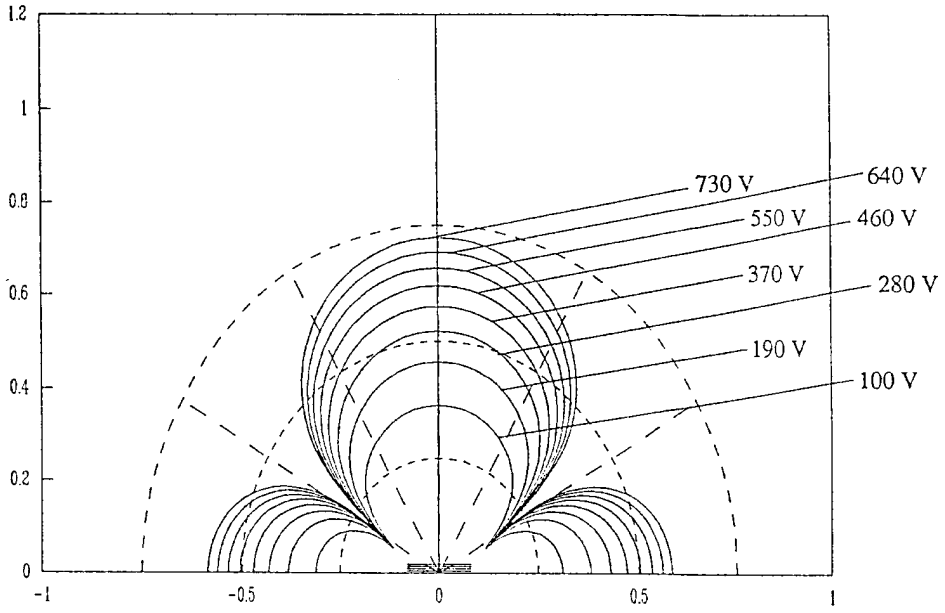


A) 0°Orientation

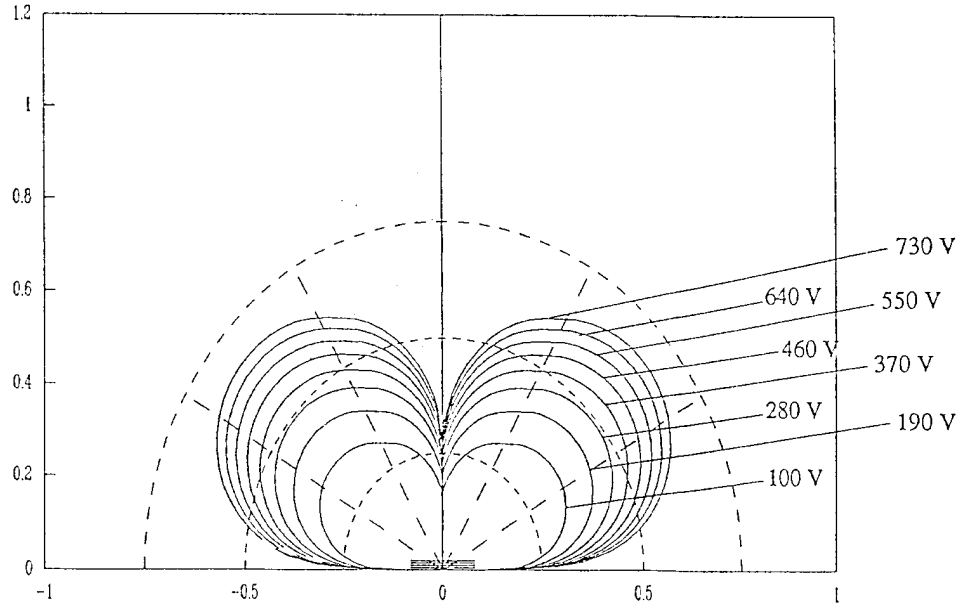


B) 90°Orientation

Figure 2-5. Charge-Up Diagram for the G01C Antenna
Antenna Voltage From 40 V to 712 V in 96-V Steps (Peak-to-Peak)
(Scale in Meters)

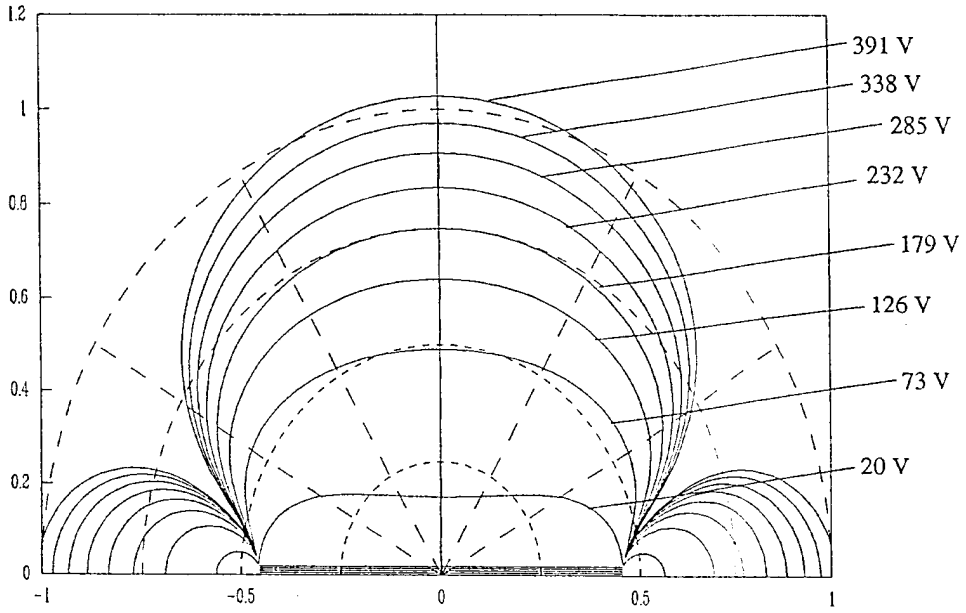


A) 0°Orientation

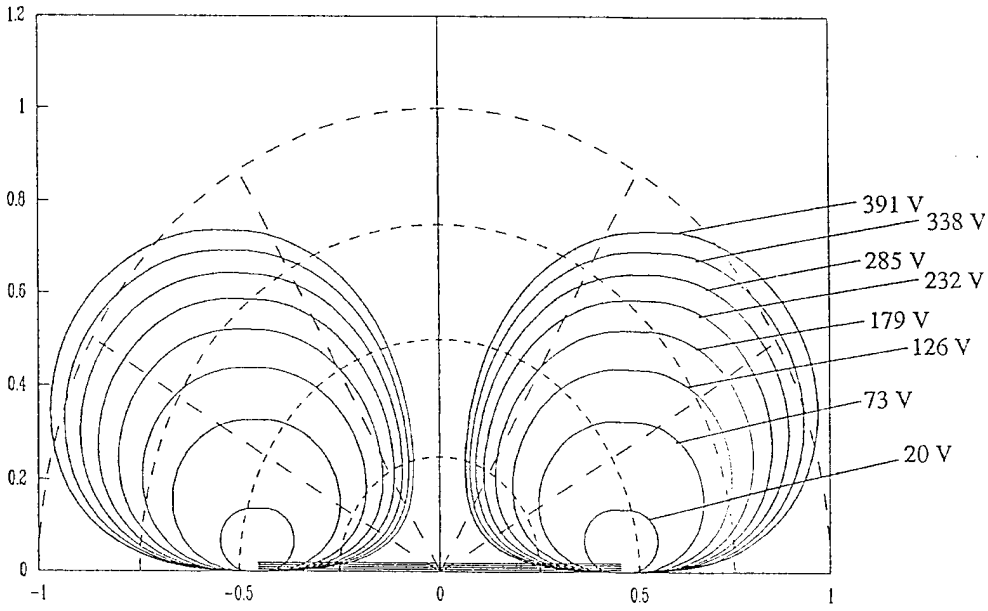


B) 90°Orientation

Figure 2-6. Charge-Up Diagram for the G02C Antenna
Antenna Voltage From 100 V to 730 V in 90-V Steps (Peak-to-Peak)
(Scale in Meters)

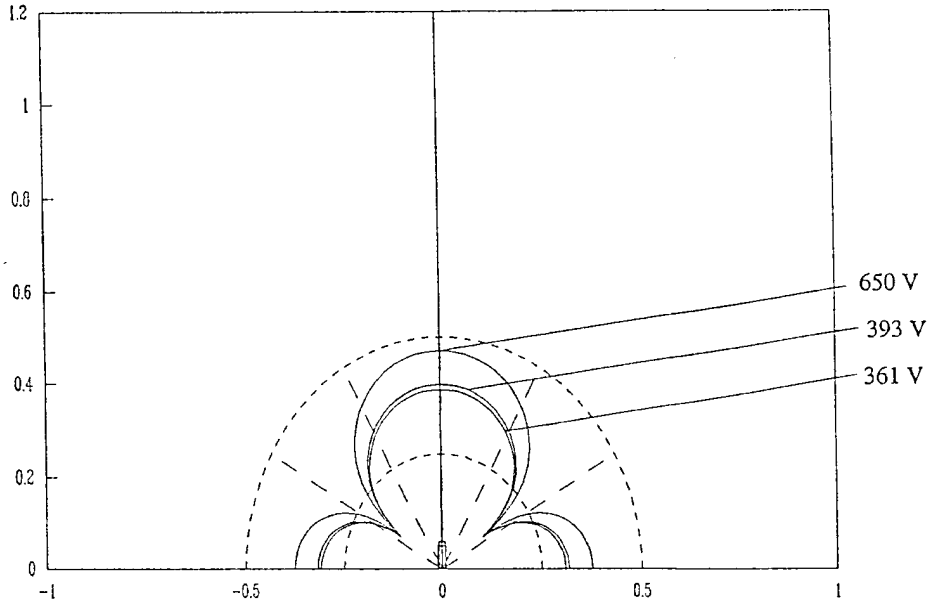


A) 0°Orientation

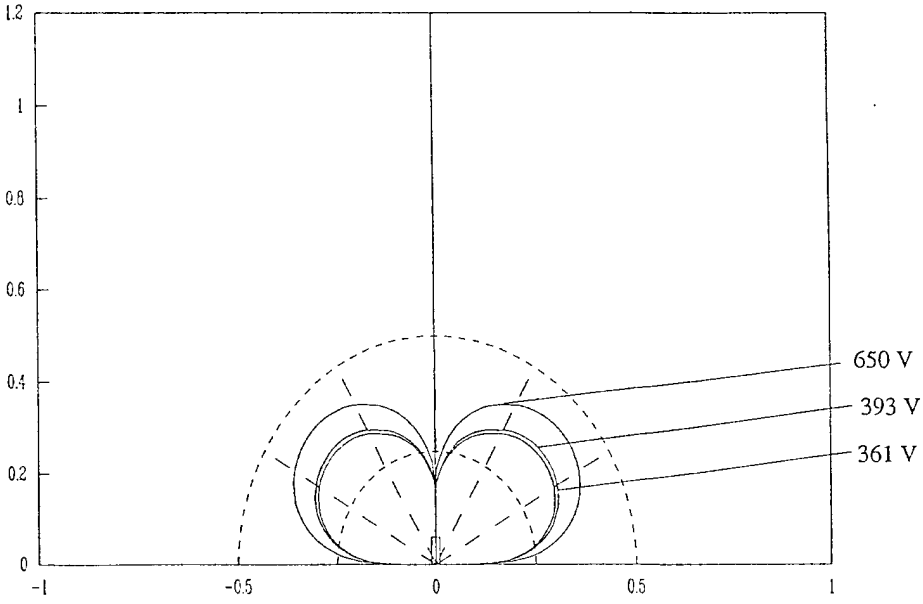


B) 90°Orientation

Figure 2-7. Charge-Up Diagram for the G03C Antenna
Antenna Voltage From 20 V to 391 V in 53-V Steps (Peak-to-Peak)
(Scale in Meters)



A) 0°Orientation



B) 90°Orientation

Figure 2-8. Charge-Up Diagram for the S01C Antenna 361 V, 393 V, and 650 V (Scale in Meters)

2.8 Separation Between Transponders

Separation refers to how close together transponders can be and still be individually read.

High selectivity means transponders can be close together while still achieving successful readings. Low selectivity means that more distance is needed between transponders in order for them to be successfully read.

The smaller the antenna, the smaller the major lobe.

The smaller the antenna, the greater the selectivity. The following list shows the TIRIS antennas in order of increasing selectivity:

Least	G03C large gate
	G02C medium gate
	G01C small gate
Greatest	S01C/S02C stick antenna

2.9 Antenna Parameters

Each antenna has an induction of 27 μH ± 1 μH, with a Q-factor larger than 100. These values are valid at room temperature and a 134.2 kHz measuring frequency.

Noise Characteristics

3.1 Influence of Noise on Readout Range

Noise has an impact on system performance. The most important consideration in solving noise interference problems is to choose the best antenna for the particular application. This section provides:

- Explanation of noise
- The effect of moving the transponder closer to the readout antenna

Noise is any signal that deteriorates the readout range of the system. The larger the antenna (surface × number of windings) the larger the noise signal that will be induced.

Homogeneous noise includes sources like other TIRIS systems at a certain distance (more than 10 meters), radio stations transmitting within the TIRIS bandwidth, other strong noise sources at a large distance from the readout antenna. Inhomogeneous noise includes sources like monitors, auto engines, other transponders within the field of the antenna, switching relays, etc., close to the readout antenna.

The readout range can be increased by orientating the readout antenna away from noise sources. It is always recommended to look for noise sources and try to eliminate them if possible.

The signal from the transponder must be larger than the noise level, otherwise the receiver will not identify the transponder. When a transponder signal is overpowered by external noise, moving the transponder closer to the readout antenna has two effects which influence the readout:

The first is better coupling between the transponder and the readout antenna (the better the coupling, the larger the induced voltage on the readout antenna).

The second is by charging the transponder capacitor up to a higher voltage, this means that the transponder is then able to transmit a stronger signal back to the readout antenna.

Figure 3-1 is a graph showing the readout range for the standard gate antennas as a function of homogeneous noise. This graph ignores government agency regulations (FCC, PTT, etc.)

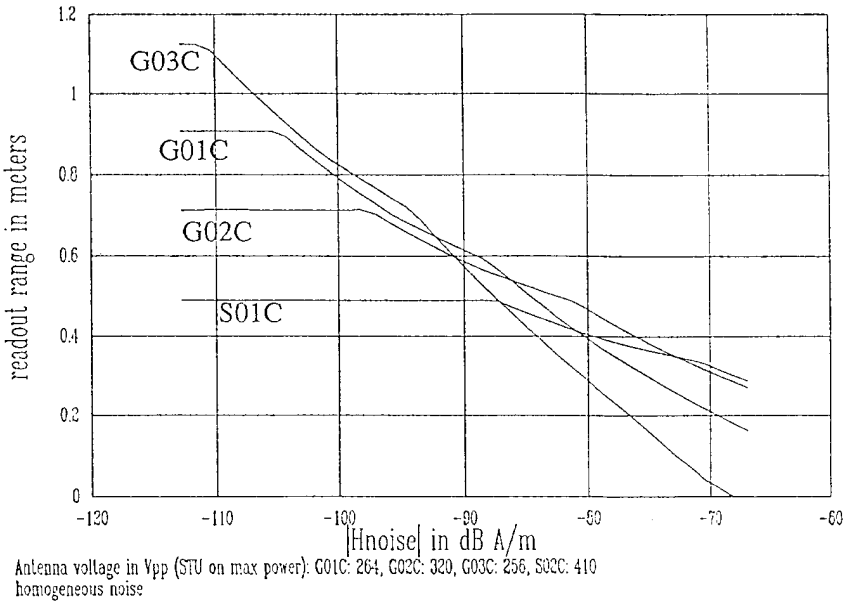


Figure 3-1. Readout Range of 32.5-mm Transponder With STU on Maximum Power (All Values Are Absolute)

Note: With cases of inhomogeneous noise, working out the reading distance is more complex and very dependent on the type of noise source. A straightforward analysis cannot be presented.

There is a relationship between the antenna voltage and the readout range in a homogenous noise environment. The figure for this relationship is established with three sections:

Vcl = 3.5 V boundary (the transponder must be charged-up to a very minimum of 3 V to be able to return its ID code – for example: in Figure 3-2 for the G03C antenna, the 3 V boundary is between 50 V and 180 V).

Noise limiting boundary (the reading distance over which a proper readout can be achieved taking noise into consideration; in Figure 3-2 for the G03C antenna, this is between 180 and 950 V_{ant}).

Vcl = 7 V boundary (the maximum charge-up level of the transponder, in Figure 3-2 for the G03C antenna, this is between 950 V and higher).

There are two principles involved in working out the read-out range:

The first principle is that the higher the antenna voltage, the higher the field strength and the larger the charge-up distances.

The second principle is that if you achieved a longer charge-up distance, the level of charge on the transponder capacitor was probably only about 5 V, thus restricting the distance over which the return signal can be read (not such a good coupling between the transponder and the read antenna). For example: if the transponder was a little closer to the reader antenna, the capacitor would have charged-up a little more (say 5.5 V) resulting in a slightly stronger returned ID signal.

Figure 3-2 gives an indication of the readout range for the standard antennas depending on the antenna voltage.

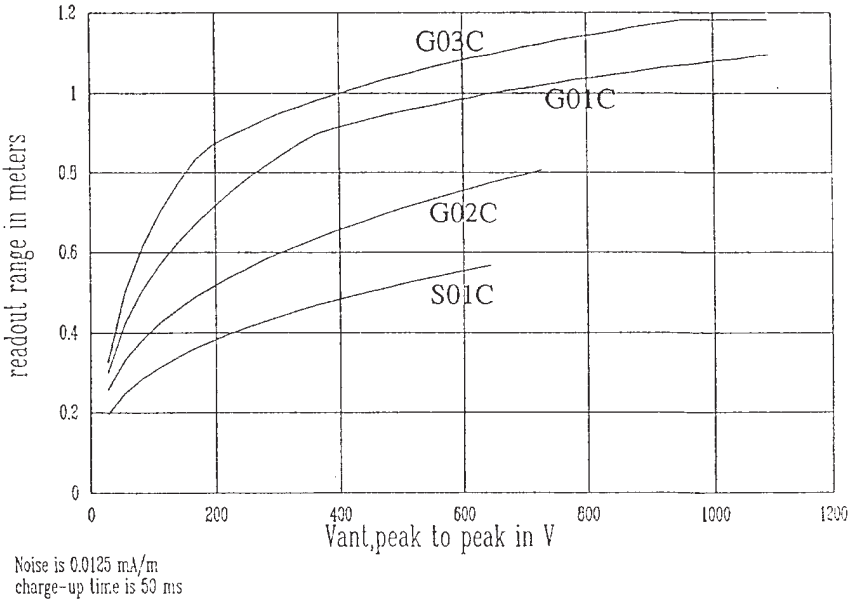


Figure 3-2. Readout Range ($V_{antenna}$)

Antenna Voltage and Field Strength

4.1 Maximum Antenna Voltage Allowed

Some countries allow a higher magnetic field strength than others. In this case, you can have a higher voltage on the antenna terminals. The higher the antenna voltage, the more power is dissipated within the antenna. At a certain dissipation you reach the maximum temperature rise allowed for the gate antennas.

Maximum temperature rise is defined as the difference between the antenna temperature at the beginning of system operation and the antenna temperature at 1 hour of system operation. For the gate antennas the maximum temperature rise allowed is 15°C and for the stick antenna 75°C. The maximum temperature rise defines the allowed maximum RMS current for each antenna.

These currents are (Ieff):

G01C: 10.6 A
G02C: 8.25 A
G03C: 12.0 A
S01C: 7.5 A (not in complete saturation)

Normally the charge-up time (TX) and receive time (RX) are respectively 50 ms and 40 ms. For certain applications it is better to have a shorter charge-up time.

When you need to calculate the antenna voltage allowed for each application, use Equation 4-1:

$$V_{ant,maximum} = 2 \times I_{eff}\sqrt{2} \times \sqrt{\frac{TX+RX}{TX}} \times 2 \times 3.142 \times 134200 \times 27 \times 10^{-6} \quad (4\text{-}1)$$

Note: This voltage is the peak-to-peak voltage of the antenna.

Example 1:

For the default transmit time (TX = 50 ms and RX = 40 ms), the maximum voltage of the G02C antenna will be 713 Vpp.

Example 2:

TX = 15 ms and RX = 35 ms, you get for the maximum antenna voltage of the G01C 1246 Vpp.

4.2 Maximum Magnetic Field Strength That Can Be Generated

There is a direct relationship between the magnetic field strength that is generated by the gate antenna and the antenna voltage on the terminals of the antenna. The maximum voltage is provided in Equation 4-1. The relationship between the antenna voltage and the magnetic field is a linear function. The magnetic field strength at 1 m and 3 m distance from the antenna appears in Table 4-1:

Table 4-1. Magnetic Field Strength Generated With 1000-V Peak-Peak Antenna Voltage

Antenna Type	H in Peak Value at 1 Meter	H in Peak Value at 3 Meters
G01C	2012 mA/m	83 mA/m
G02C	707 mA/m	26.5 mA/m
G03C	3680 mA/m	168.2 mA/m
S01C	216 mA/m	8 mA/m

The antenna voltage of Table 4-1 is for each antenna at 1000 $V_{peak\text{-}to\text{-}peak}$. Because the relationship is linear, you can calculate the magnetic field strength for a different antenna voltage very easily. You just divide the antenna voltage by 1000 and multiply the result with the value in Table 4-1.

The values above are valid for antenna inductance of 27 µH; because the TIRIS gate antennas have a small tolerance, you can always use this value for them. If you want to know the field strength exactly, you must measure the inductance, then divide the measured inductance by 27 µH and multiply this value by the magnetic field strength you calculated (for the antenna voltage previously calculated).

4.3 Magnetic Field Strength Boundaries for Countries With RMS Regulations

Countries where the Government Agency regulations allow for RMS calculations have an advantage over countries that do not use RMS. For these countries, it is possible to use a higher magnetic field strength, which means that TIRIS installations do not need such a long charge-up time.

The relation between charge-up/receive time and magnetic field strength is shown in Equation 4-2:

$$H_{rms} = H_{peak} \times \frac{1}{\sqrt{2}} \times \sqrt{\frac{TX}{TX+RX}} \quad (4\text{-}2)$$

Comment: USA has a RMS in a 100 ms window. This means TX + RX = 100 ms. TX must be the worst case (longest used charge-up time).

Example: For the standard 50 ms charge-up and 40 ms receive time:

TX = 60 ms and TX + RX = 100 ms.

Speed Applications (Detecting Moving Transponders)

5.1 Introduction

For applications when the transponder to be read is moving, the readout length is important (see D on Figure 5-1). You can calculate the worst case maximum speed of the transponder past the antenna. This is based on the dimension of the major lobe as shown in Figure 5-1.

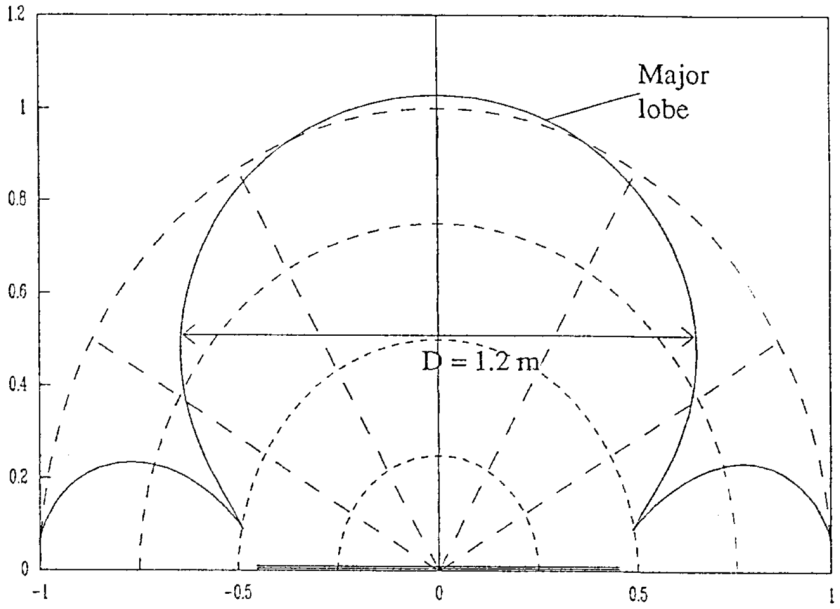


Figure 5-1. Maximum Transponder Speed

With speed applications it is in the major lobe that identification of the transponder is made. However, when a transponder approaches the antenna, it is charged up a little by the side lobes of the readout pattern. Before the transponder enters the major lobe, it is subject to no magnetic field for a short time, during this short time if the transponder has built up enough energy, it starts to transmit its ID code. That transmission may not be completed. Then, it enters the major lobe where it is charged-up again.

To calculate the maximum speed, use this method:

1. A transponder must be charged up to 5 V or more (charging-up is explained in Chapter 2)
2. Make an intersection at the place where the transponder crosses the major lobe. Determine the distance between the 5 V boundaries of the major lobe (D on Figure 5-1).

   The transponder needs TX+RX seconds to be read out, so the maximum speed will be: $VEL_{max} = D/(2 \times (TX+RX))$.

Example: (see Figure 5-1)

Antenna is G03C

Distance to antenna is 0.5 meter

D = 1.2 meter

TX+RX = 90 ms

VEL_{max} = 24 km/h

This section is intended to provide information and examples regarding the two most important system constraints (transponder charge-up level and field strength), so that if any of the parameters in your system have to be changed, you can work it out using these examples as a basis.

5.2 Shorter Charge-Up (TX) Pulses for Speed Applications

The values in Table 2-1 are only valid in TX = 50 ms and RX = 40 ms. For countries with RMS and CISPR regulations, the antenna voltage can be higher for shorter TX pulses. Use Equation 4-1 to calculate the maximum allowed antenna voltage (this level is the temperature limit of the antennas). With Equation 4-2 you can calculate the antenna voltage for shorter TX pulses (only valid for countries with RMS FCC regulations); this voltage must always be lower than that calculated with Equation 4-1:

There are two constraints:

1. V_{cl} = 5 V
2. H_{rms} = constant

Constraint 1:

For TX = 50 ms:

$V_{cl} = 5 = A \times (1 - e^{TX/RxC})$

where:

R = 302777 Ω

C = 120 nF

A = 6.689

For TX = TX_b

Where $_b$ = time chosen

$$A_b = 5/(1 - e^{TX/RxC}) \quad (5\text{-}1)$$

With a shorter TX pulse you get a higher coefficient 'Ab'. This means that the peak value of the magnetic field strength must be Ab/A times higher than in the case of 50 ms charge-up time, to get the same charge-up voltage.

A = the calculated value for 50 ms.

Constraint 2:

$H_{50ms,peak}$ is the magnetic field for 50 ms charge-up time:

$$H_{50ms,\,peak} = \frac{H_{rms}}{\frac{1}{\sqrt{2}} \times \sqrt{\frac{TX}{TX+RX}}} = \frac{H_{rms}}{0.527}$$

For a different TX you have the magnetic field strength multiplication:

$$\frac{H_{TX,\,peak}}{H_{50ms,\,peak}} = \frac{\sqrt{2} \times 0.527}{\sqrt{\frac{TX}{TX+RX}}} = \frac{0.746}{\sqrt{\frac{TX}{TX+RX}}} \quad (5\text{-}2)$$

To find the correct charge-up time, TX must conform to Equation 5-1 and Equation 5-2. Unfortunately this is not possible. When you choose a shorter TX pulse, the magnetic field strength can become higher as shown in Equation 5-2, but never high enough to charge the transponder to 5 V as in the case with 50 ms.

Table 5-1 shows the antenna voltage multiplication factor for different charge-up times and the resulting charge-up voltage in the transponder (V_{cl}). You can calculate the maximum allowed antenna voltage by first finding out from Table 2-1 what the antenna voltage level is for 50 ms, then multiplying it by the multiplication factor given in Table 5-1 for the TX time selected (or calculate it using Equation 5-2).

Table 5-1. Charge-Up Times, Multiplication Factors, and Transponder Charge-Up Levels

TX	Multiplication Factor for Antenna Voltage	V_{cl}
90 ms	0.91	5.58
50 ms	1	5
30 ms	1.167	4.39
15 ms	1.547	3.5
10 ms	1.862	3
5 ms	2.6	2.24

Example: Using Antenna G01C in France:

The antenna voltage (for 50 ms) allowed is = 688

If TX = 90 ms then $688 \times 0.91 = 626\ V_{ant}$

For short TX pulses (and antenna voltage adjustment) the transponder is not charged-up enough at the same distance from the antenna as in the case of a 5 V charge-up in 50 ms. You can see from Table 5-1 that in some cases V_{cl} is lower than 3 V, which means that the transponder voltage is too low to transmit back any ID code. This means that you have to look for a different charge-up voltage for example: 7 V at 50 ms (move the transponder closer to the antenna). Then you get:

$7/5 \times 2.24 = 3.1$ V at 5 ms (enough to transmit back)

For CISPR countries, it is not possible to give such a calculation.

Mechanical Characteristics

This section describes the mechanical parts of the TIRIS antennas.

6.1 Mounting the Antenna

Figure 6-1 shows the mounting hole dimensions for the three types of gate antenna. Gate antennas can be mounted on nonmetallic surfaces using non-metallic M6 bolts. Use plastic washers to increase shock resistance. Tighten the bolts with a maximum torque of 8 N-m (6 ft-lb). When mounting the antenna on a wall, use spacing washers to prevent bending of the antenna frame.

Stick antennas can be mounted in plastic snapfit holders.

Avoid the presence of metal parts close to the antenna. Metal parts larger than the size of your hand disturb the field pattern and cause lower readout range.

The connection leads can withstand a pull force of 100 newton (22.5 lb) in any direction.

6.2 Cleaning the Antenna

TIRIS antennas may be cleaned with warm water and liquid soap. If you use high pressure water sprayers, be careful with the connection lead outlet.

6.3 Chemicals

TIRIS antennas are designed for use in an industrial environment. The antenna frames are resistant to most common chemicals.

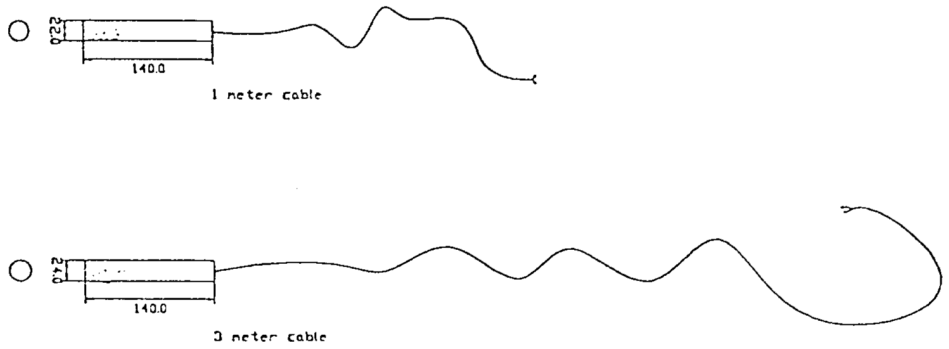
6.4 Metal in the Environment

Metal parts can disturb the TIRIS system in two ways: by altering the readout pattern (eddy currents and ferromagnetic influence) and by detuning the transponder's oscillator circuit and detuning the charge-up system.

Try to avoid metal in the area around the antenna. When this is not possible re-tune the antenna after installation.

6.5 Connection Leads

The whole antenna is a vital part of the TIRIS system. Altering the length of the connecting lead or replacing the connectors affects the inductance and quality factor. This can decrease the performance of the system. The Figure 6-2 shows the dimensions of the connector leads.



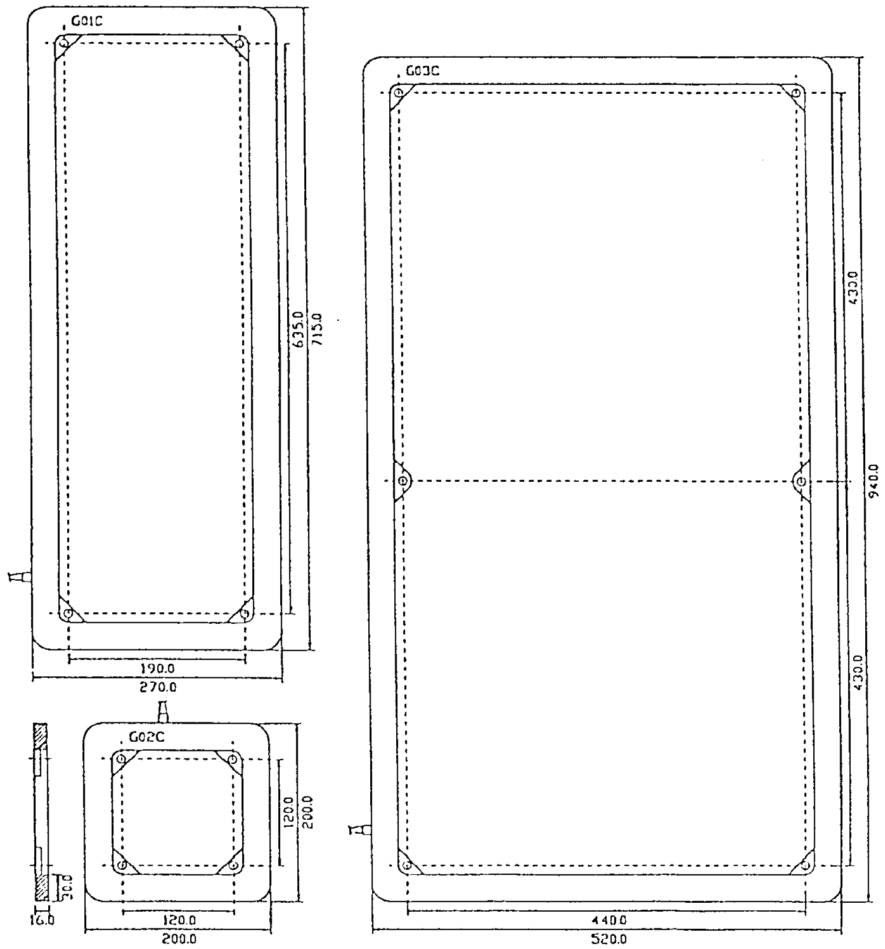


Figure 6-1. Antenna Dimensions

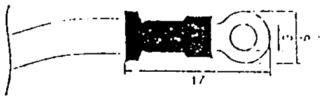


Figure 6-2. Antenna Connector

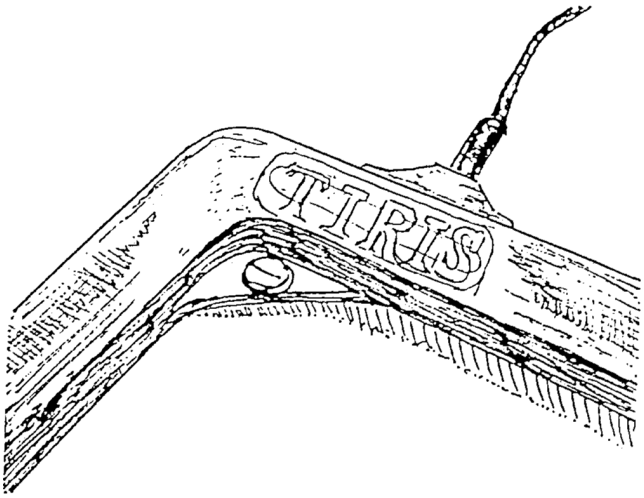


Figure 6-3. Mounting a Gate Antenna

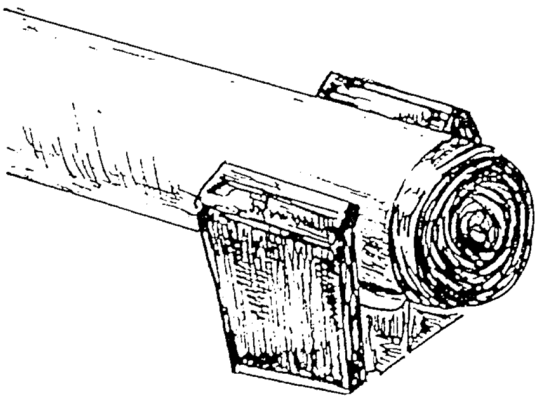


Figure 6-4. Mounting a Stick Antenna

Brief Theory of Magnetic Induction

This appendix has only been included to help in general understanding of how induction works, the illustrations used in it are based on Maxwell equations. The description is, of necessity, only superficial as it would become very complex to go into more detail. If you would like more information or detail, please contact your local TIRIS Application Center.

A.1 Description

When electric current flows through a conductor, a circular magnetic field develops around the conductor with its radius perpendicular to the conductor. Figure A-1 and Figure A-2 show the magnetic field lines as seen in a cross-section of the system.

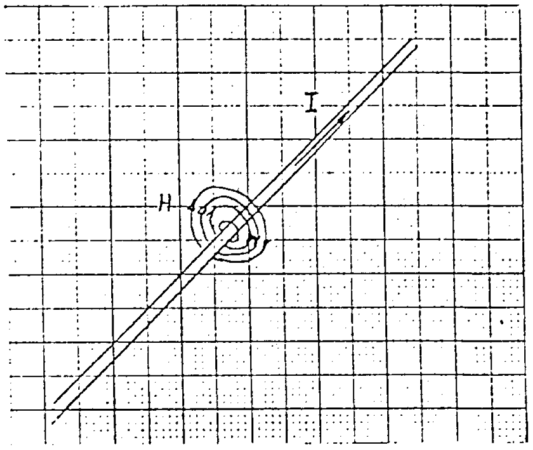


Figure A-1. Magnetic Field Distribution Around a Single Conductor, Side View

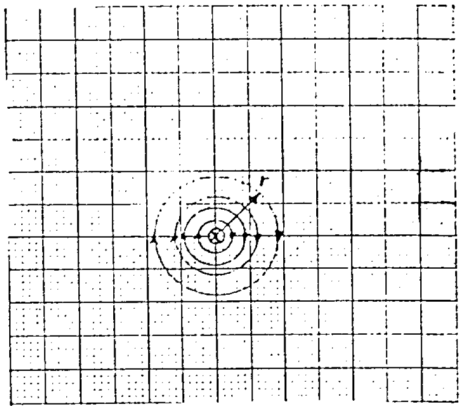


Figure A-2. Magnetic Field Distribution Around a Single Conductor, Cross-section View

In this example, current flows away from the observer, which makes the magnetic field lines travel clockwise. The magnetic field strength at each point around the conductor is positively correlated by the factor 1/r, in which r is the radius from the conductor to a given point. When two conductors are parallel with the current flowing in the opposite direction from one conductor to the other (see Figure A-3), the field lines in between the conductors add together (amplifying each other). The field density increases. When the conductors are shaped into a coil form (called an inductor, see Figure A-4), the magnetic field lines are distributed as illustrated.

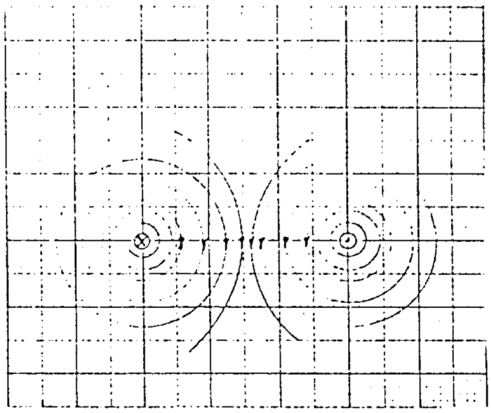


Figure A-3. Magnetic Field Distribution Around a Two Parallel Conductor

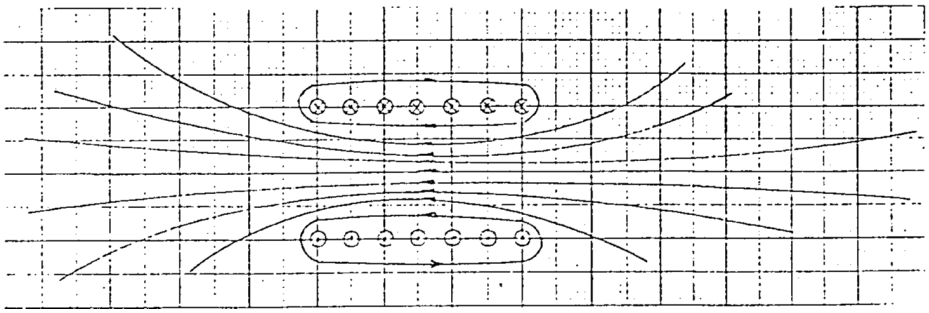


Figure A-4. Field Line Distribution Around a 6-Turn Inductor

This is the field distribution for a magnetic dipole. This shape causes the magnetic field lines to extend most effectively in distance. When AC current is applied to the inductor, the magnetic fields generated will alternate accordingly. For instance, with the TIRIS system, an alternating current of 134.2 kHz is used. This means 134200 alternations per second for the generated magnetic field.

Theory of Coupled Inductors

Five inductors are illustrated in Figure B-1. Inductor I is the field-generating (transmitting) inductor. It is connected to an AC current source. The other four are placed in proximity.

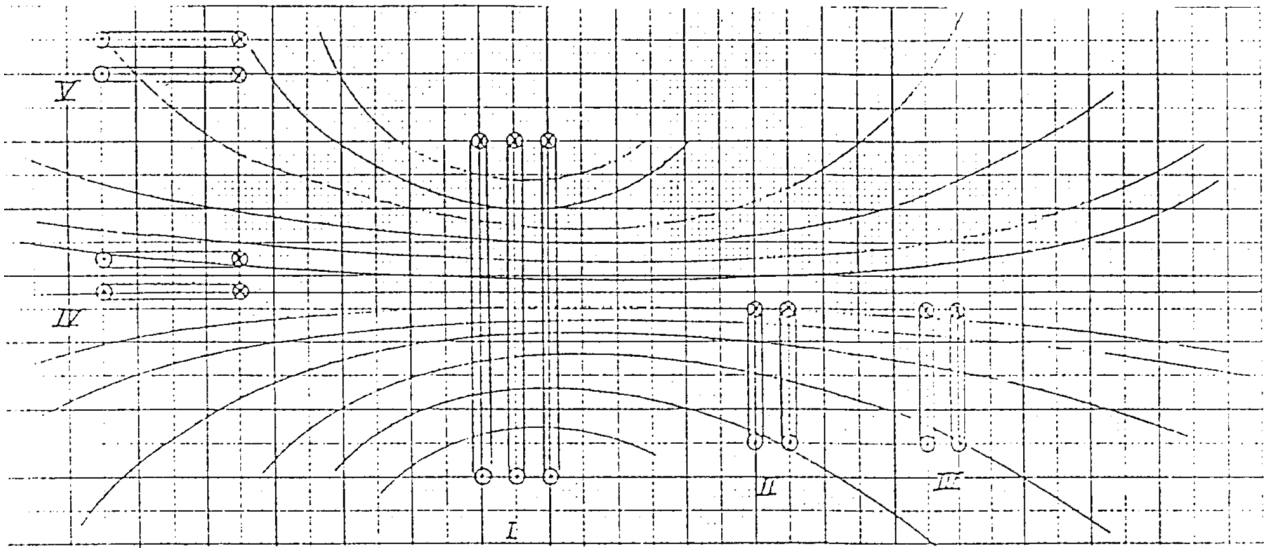


Figure B-1. Coupled Inductors

If the receiving inductors share field lines with the transmitting inductor, a current will be induced in them. The amount of current induced depends on the number of field lines that the receiving inductors share with the transmitting inductor. In other words, it depends on the coupling factor. The coupling factor can be anything between 0 (no field lines shared between the two inductors) to 1 (all field lines are shared).

Figure B-1 shows four different coupling situations. The receiving inductors II and III show the effect when the inductor is placed further away from the transmitter without changing the orientation angle (0° orientation). Inductor II shares more field lines with the transmitter than does Inductor III, because the field is spreading out when moving away from the transmitter. The field gets less dense. Inductor IV shows what happens if the receiver inductor is perpendicular to the transmitter while placed on the transmitter inductor center line. No field lines are shared anymore, although the distance is relatively small (90 degrees orientation). Therefore the coupling here will be 0. For inductor V, the orientation angle was not changed. Only the location was moved away from the center. Because of the spreading-out of the field, the field lines are shared again between the two inductors. A coupling exists again.

The design of the TIRIS tube transponder antenna is based on a ferrite inductor instead of the air coils as illustrated on Figure B-1.

However, the basic principles behind the coupling theory, as previously described, are valid for both types of inductors. It is possible to go beyond the concept of field lines to a mechanism that helps one better visualize the readout performance with regard to distance and angle. In the world of antenna design, this is done by means of radiation patterns.

Glossary of Terms

This part of the manual provides a glossary of the terms and phrases used in this manual together with a short description of the meaning of those terms.

agency regulations (FCC, PTT)	Every country has its own regulations regarding the level of RF transmission allowed. These levels vary from country to country and are set by the relevant government agency in that country (FCC in USA, PTT in Germany, etc.)
allowed magnetic field strength	The level of RF transmission is checked by measuring the magnetic field strength of the transmitted signal. The measuring distance and level depends on the regulations applied by the individual countries.
antenna voltage	The level of RF transmission from the antenna depends on the voltage applied to the antenna, the antenna voltage is determined by which antenna is to be used and the country in which it is to be used.
charge-up diagram	(Also referred to as an isofield diagram), this is a diagram showing the distance at which the transponder will be "charged-up" to a specified voltage (specified on the diagram). Moving inside these boundaries results in a higher charge-up level in the transponder. The charge-up diagram depends on: the transponder antenna, the voltage on the readout antenna, and the charge-up time.
charge-up time (TX)	The time that the readout antenna is transmitting an energizing signal to the transponder.
CISPR	A method of measuring field strength depending on the pulse/period ratio, this is done by a quasi-peak detector in the test receiver. A higher ratio decreases the level of the measured field strength, while the peak value has the same level. (Extracted from CISPE 1/16 volume 2).
coupled inductors	When a current is applied to an inductor, it transmits lines of field strength; if these lines cross another (receiving) inductor, these two inductors are then coupled.
external noise	Noise emanating from other equipment in the vicinity (for example: Video Display Units)
gate antennas	TIRIS currently uses two types of antenna: gate and ferrite rod antennas. Gate antennas are rectangular and consist of litze wire coil surrounded by a plastic mold.
homogeneous noise	General noise from all sources, such as car engines, transmitters, and so on (independent of the location of the noise source).
ID code	The individual code transmitted by the transponder when it is interrogated is the ID (identity) code.
inhomogeneous noise	External noise sources close to the field of the antenna (such as switching relays or monitors) that can effect the antenna's ability to receive the transponder's signal (place dependant).

isofield diagram	(Also referred to as a charge-up diagram), this is a diagram showing the distance at which the transponder will be charged-up to a specified voltage (specified on the diagram). Moving inside these boundaries results in a higher charge-up level in the transponder. The charge-up diagram depends on: the transponder antenna, the voltage on the readout antenna, and the charge-up time.
magnetic induction	The magnetic field strength formed around a wire when a current passes through it.
major lobe	The field strength developed by an antenna forms a major lobe and two or more minor (smaller) lobes.
noise sensitivity	How much a system is affected by noise is defined as noise sensitivity.
orientation	The angle of the transponder with respect to the antenna: 0° For Gate antenna = transponder at an angle of 90° to the antenna For Ferrite rod = transponder in line with the antenna 90° For Gate antenna = transponder parallel to the antenna For Ferrite rod = transponder at an angle of 90° to the antenna
readout antenna	The antenna used to charge-up and then readout the transponder.
readout diagram	A graphical indication of the antenna and transponder showing the "envelope" or area within which the transponder can be charged up and the resulting signal read.
readout range	The distance between the antenna and transponder at which the transponder can be charged up and the resulting signal read.
readout speed	Some utilizations of the system require that a moving transponder be read. The speed at which the transponder can be moving and still be read is the readout speed
receive time (RX)	The time that the system is not transmitting (during this time the transponder sends its ID to the antenna).
RMS	Root Mean Square, a method of measuring AC voltage whereby the indicated voltage provides an average roughly the same as a DC voltage of the same level.
selectivity (high)	A system with high selectivity can more accurately "select" a transponder, in practice this means that transponders can be fairly close to each other and yet still be successfully read.
selectivity (low)	If a system has low selectivity it means that there has to be more distance between transponders in order to read them successfully.
separation between transponders	Separation refers to how close together transponders can be and still be read.
side lobes	The two or more minor (smaller) lobes of field strength developed by an antenna.
standard antennas	This manual describes the five antennas currently being produced by TIRIS. Other antennas can be used, but they must satisfy certain restraints.
stick antennas	TIRIS currently utilizes two types of antenna: gate antennas and stick (or ferrite rod) antennas. Stick antennas are cylindrical in form and consist of ferrite rods with litze wire coiled around them.
transponder charge-up	The time that it takes for the capacitor in the transponder to charge up to 5 V to enable it to transmit its ID signal back to the antenna.

transponder orientation	The angle of the transponder with respect to the antenna 0° For Gate antenna = transponder at an angle of 90 degrees to the antenna For Ferrite rod = transponder in line with the antenna 90° For Gate antenna = transponder parallel to the antenna For Ferrite rod = transponder at an angle of 90 degrees to the antenna
V_{cl}	$Voltage_{charge\ level}$, the level of the charge on the transponder's capacitor.

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