TI-RFid
A TEXAS INSTRUMENTS TECHNOLOGY

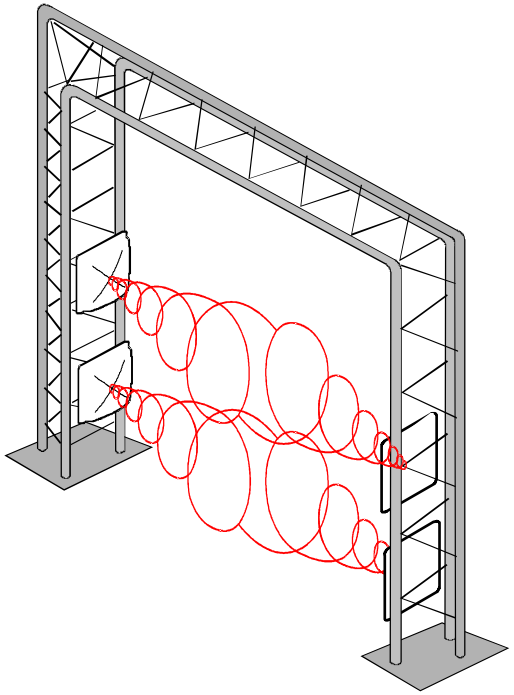
UHF Applications

Installation Hints

- This presentation looks at the background to installing a UHF system to read incoming or outgoing product:
  - Antenna selection
    - Linear Vs Circular polarized
    - dBi vs. dBic
  - Feeder cables
    - Selection
    - Routing
    - Losses
  - Power limits
    - Watts vs. dBm
    - ERP vs. EIRP
  - Setting power levels
  - Signal propagation and attenuation
  - Label positioning
  - Inlay selection

The Reading System

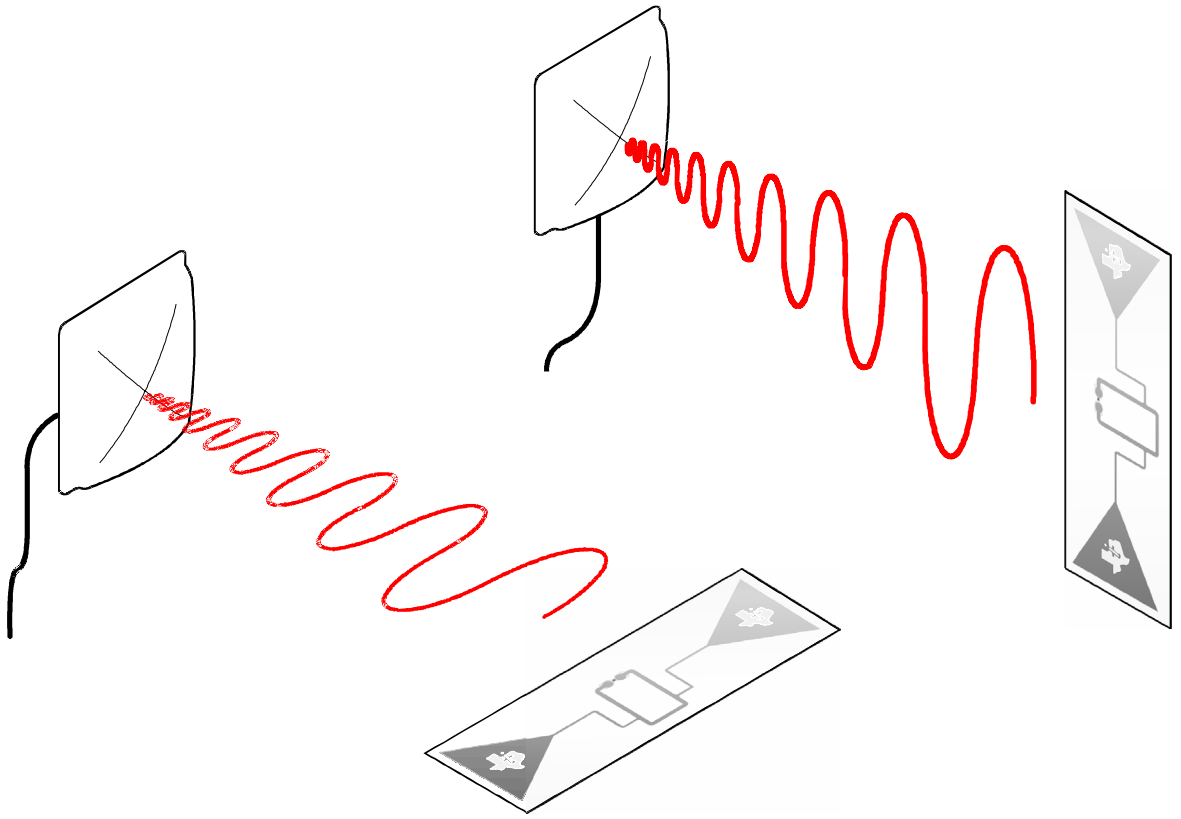
- Unless all UHF labels passing a reader's antenna are uniformly positioned, it is most likely that a multi-antenna portal is used.
  - Portal readers typically multiplex 4 × patch antennas



  - These antennas can be linear or circular polarized

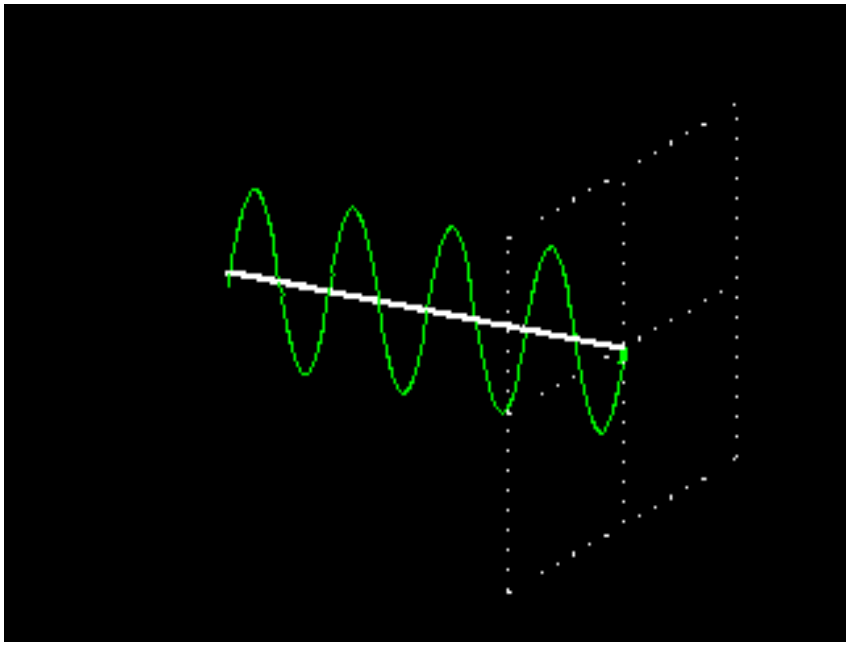
Linear Antenna Polarization

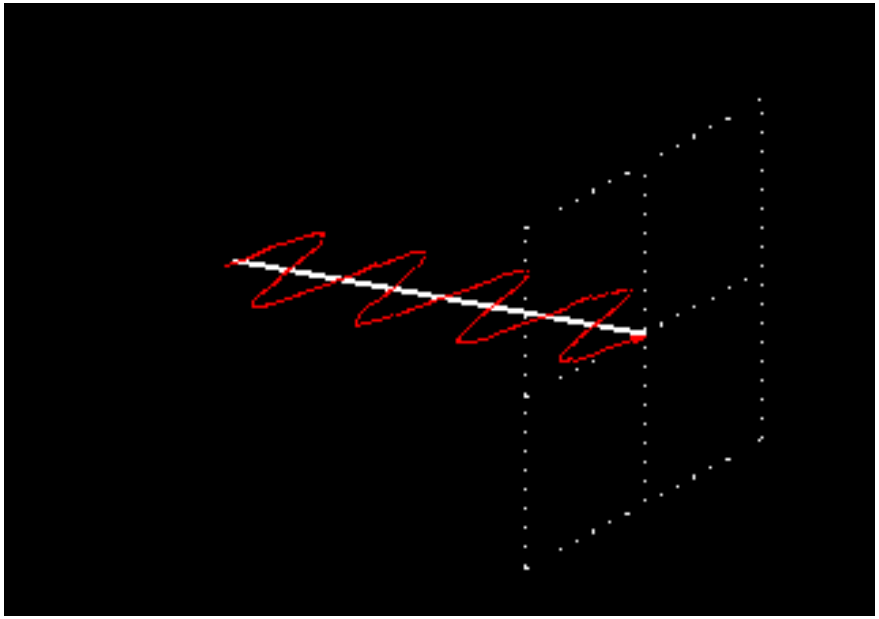
- With linear polarized antennas:
  - A tag's performance depends on its orientation with respect to a linear polarized antenna



Linear Antenna Polarization

- Vertically polarized:

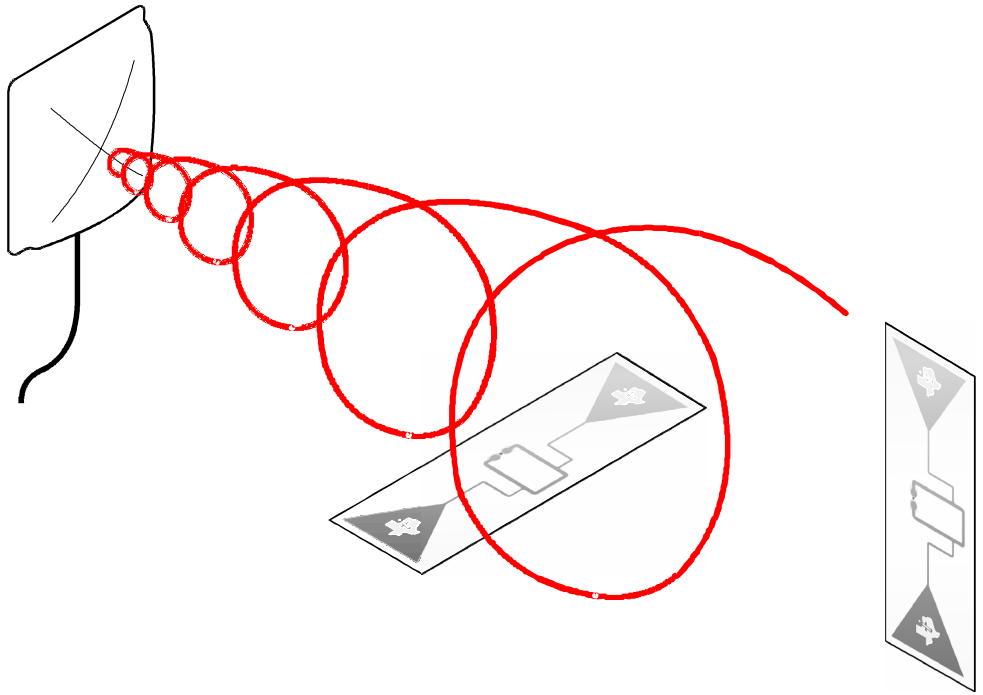




- Horizontally polarized:

Circular Polarized Antennas

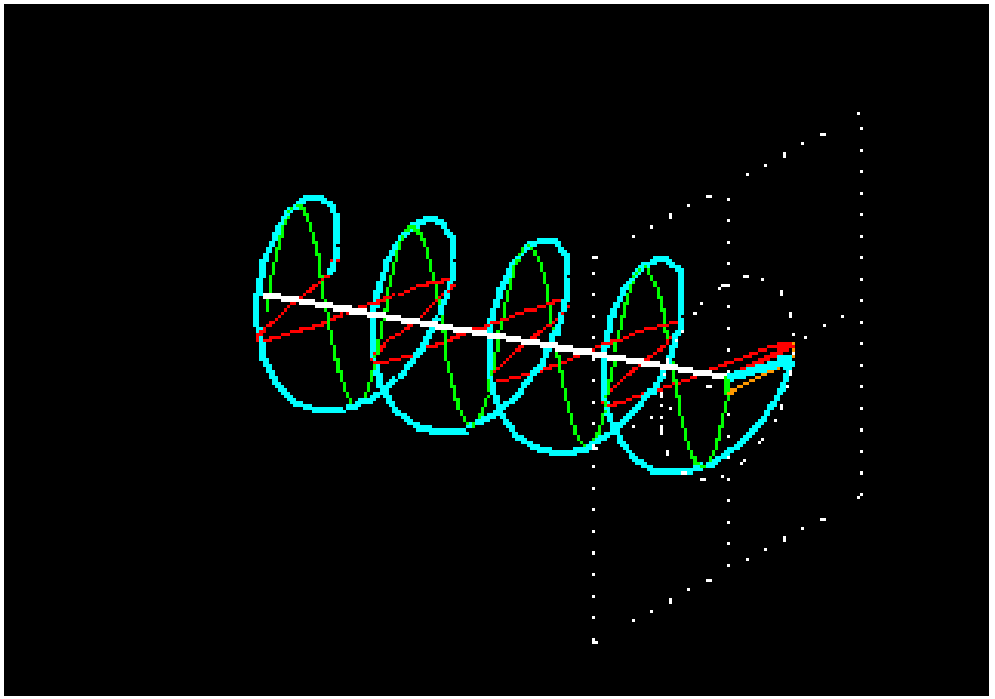
- With circular polarized antennas, tag orientation is less critical.
  - The helical nature of the field from a circular polarized antenna allows it to read tags in more than one orientation.



  - The down side of circular polarized antennas is that their output is less than linear antennas (approximately 50% down).

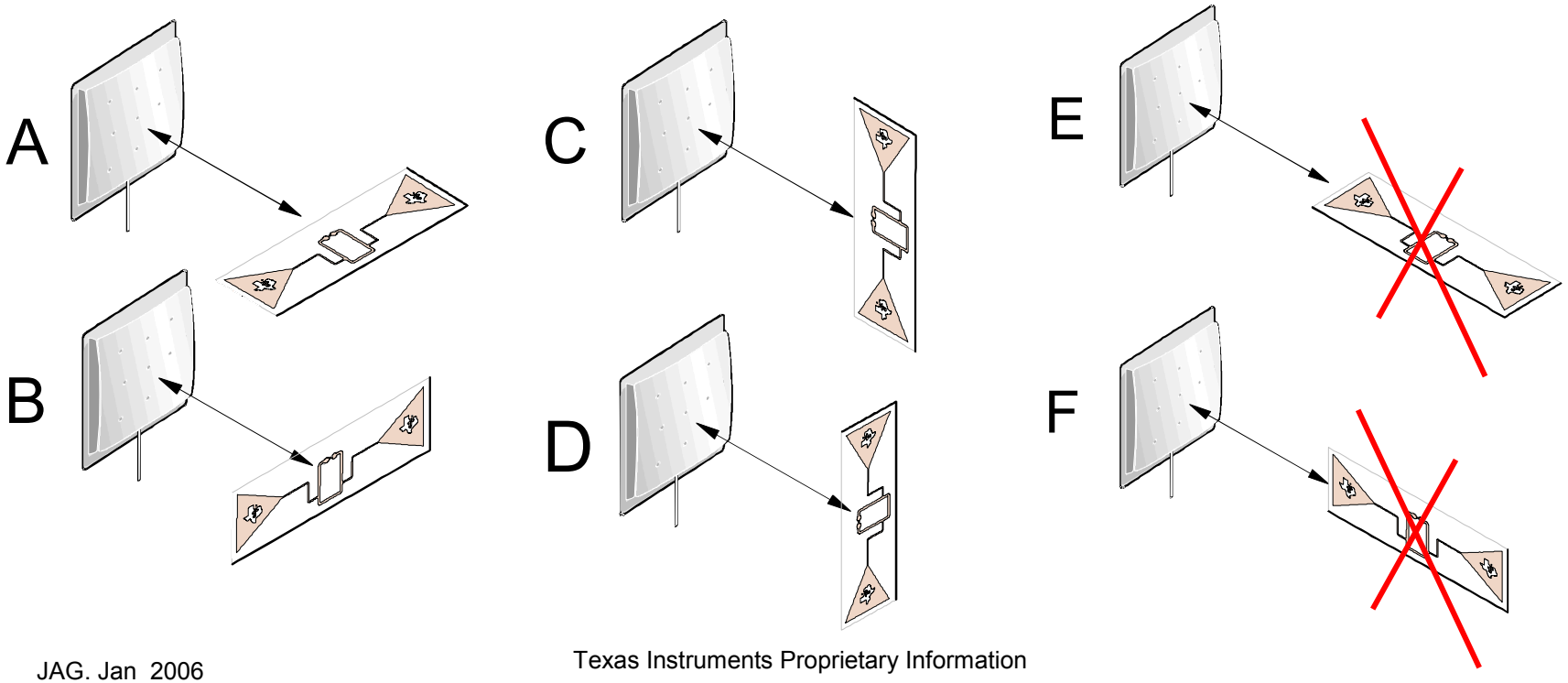
Circular Polarized Antennas

- Circular polarization.



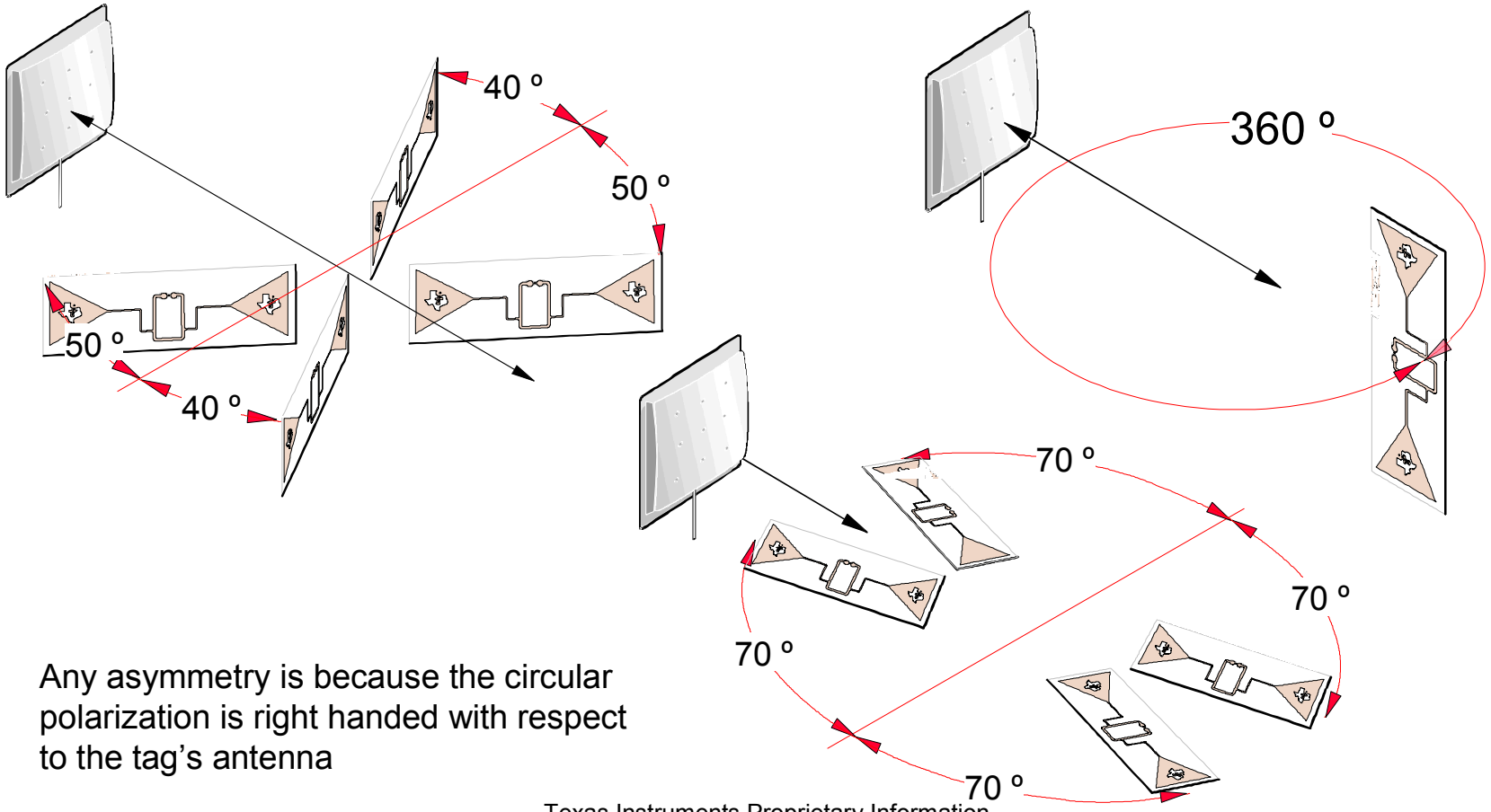
Circular Polarized Antennas

- With circular polarized antennas
  - The tags read best in orthogonal orientations A & B.
  - Orientations C & D are only slightly less effective.
  - Orthogonal orientations E & F are not recommended.



Circular Polarized Antennas

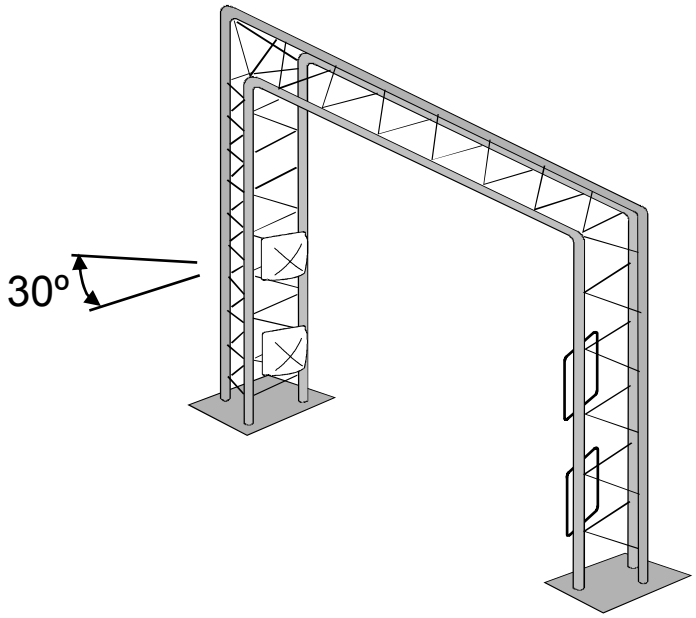
- With circular polarized antennas
  - Tags will read in certain rotated positions (between the arrows)



Any asymmetry is because the circular polarization is right handed with respect to the tag's antenna

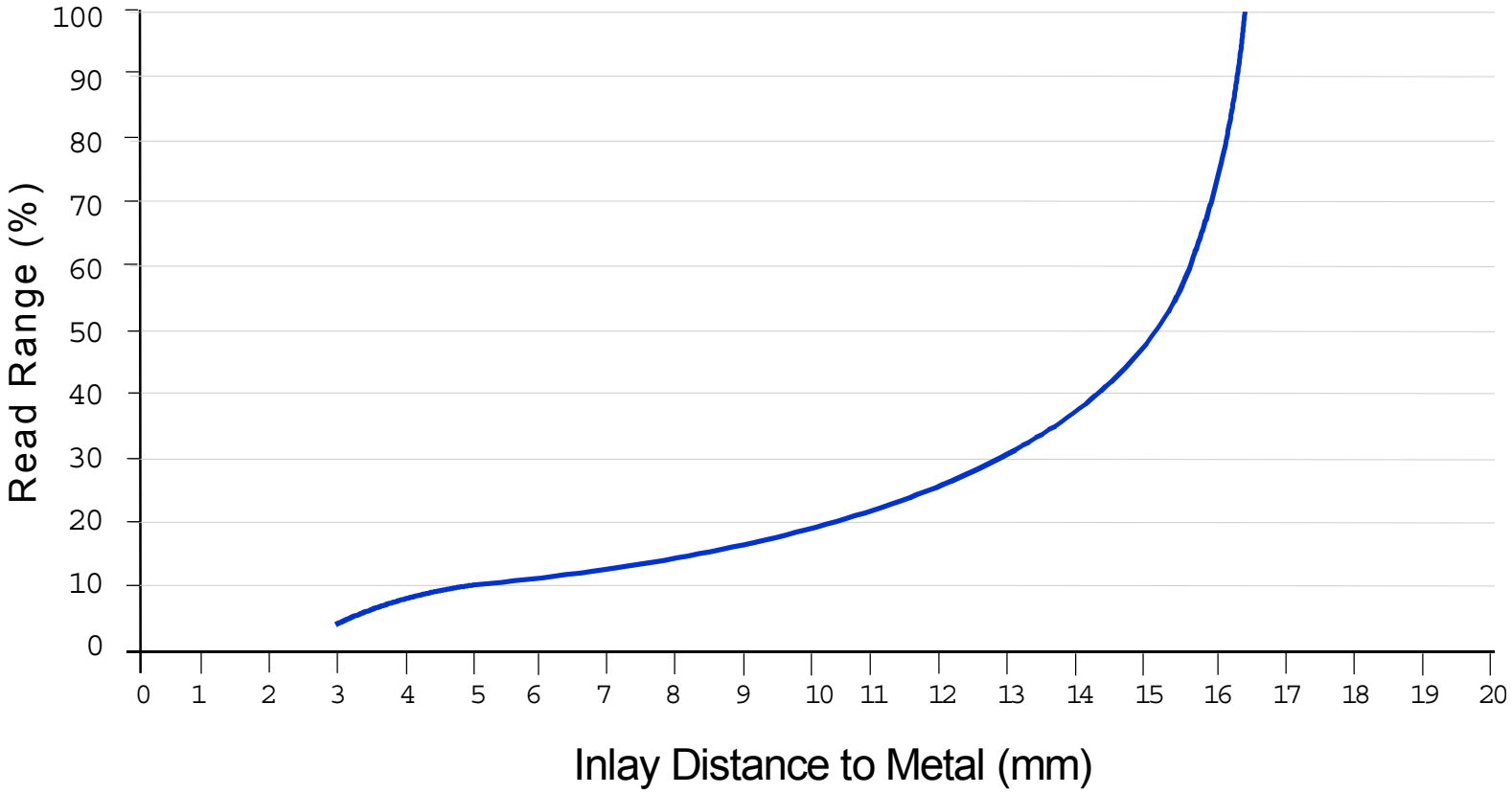
The Reading System

- Unless all UHF labels passing are parallel to the antennas. The antennas will be more effective at reading tags in different orientations if they are at a slight angle (20º – 30º)



  - The best angle will have to determined by experimentation
  - It will also reduce 'Ghost readings' from the vehicle side

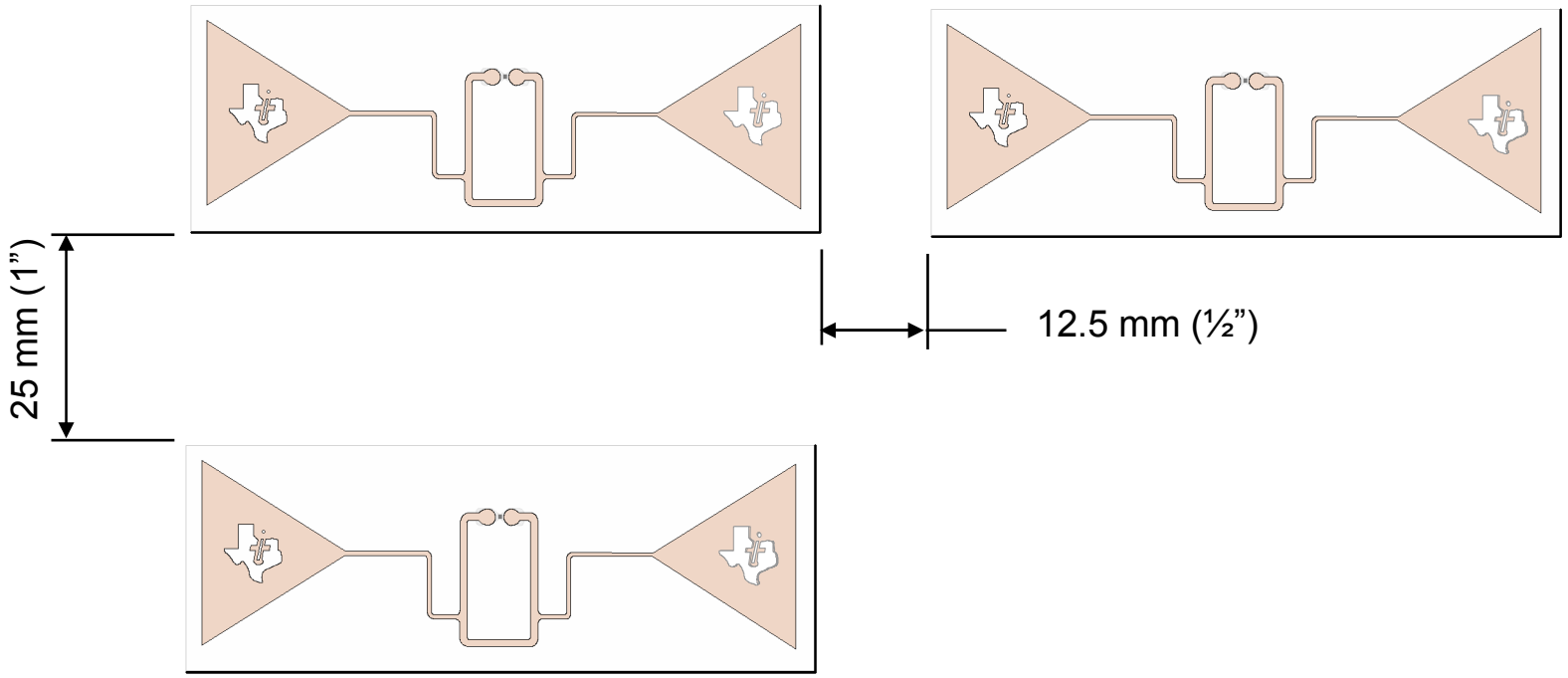
Tag to Metal Separation



Note. The metal will have a de-tuning effect when close to the reader's antenna,

Inlay Separation

- Inlays can couple with one-another if they are too close
  - For optimum performance the following are the suggested minimum distances the inlays should be apart

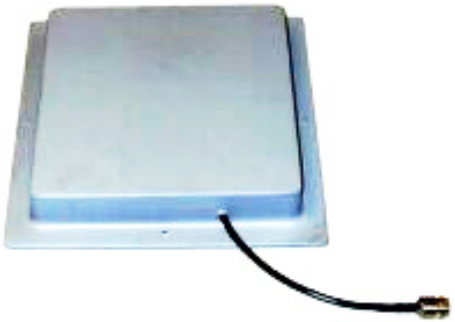


Circular Polarized Antennas

- One common circular polarized antenna is made by Cushcraft.
  - Their S8658PC antenna has the following characteristics.

  - Frequency 865 MHz ~ 965 MHz.
  - Gain 8.5 dBiC
  - 3 dB bandwidth of 65º × 65º.
  - VSWR 1.5:1
  - http://www.cushcraft.com

- Another circular polarized antenna is made by Poynting
  - Their Patch-A0003-02 antenna has the following features



  - Frequency 860 MHz ~ 930 MHz.
  - Gain 7 dBiC
  - VSWR 1.5:1
  - http://www.poynting.co.za

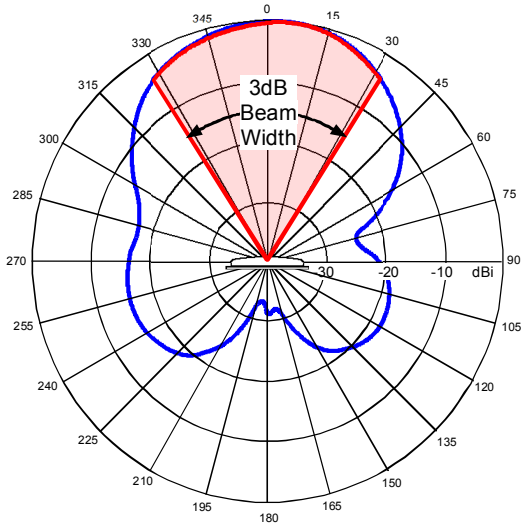
Circular Polarized Antennas

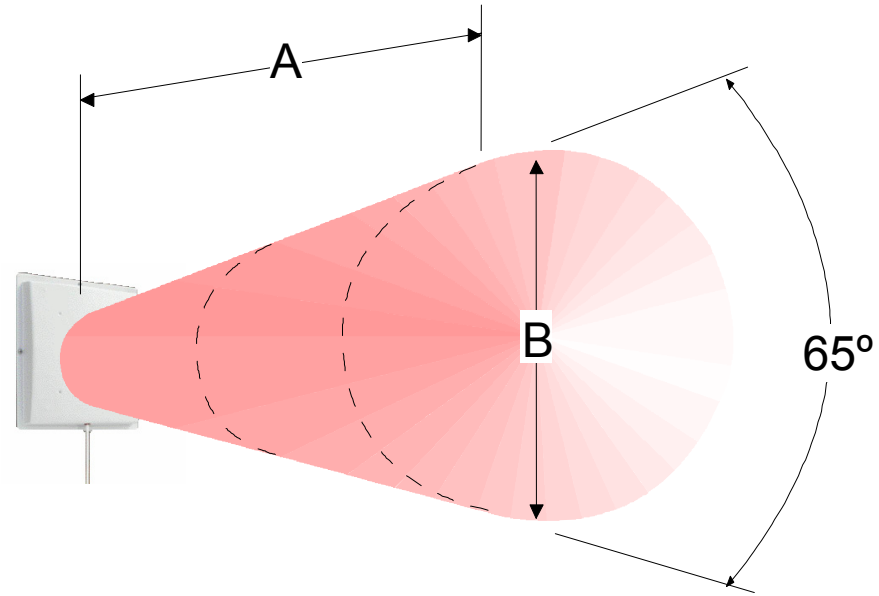
- A third circular polarized antenna is made by Kathrein-Scala.
  - Their 25-200 Series LHCP Panel antenna has the following characteristics.

  - Frequency 865 MHz ~ 928 MHz.
  - Gain 8 dBic
  - 3 dB bandwidth of 65º × 55º.
  - VSWR < 1.3:1
  - http://www.kathrein-scala.com

Circular Polarized Antennas

- A 3 dB bandwidth, 65º × 65º gives the following approximate read zone.

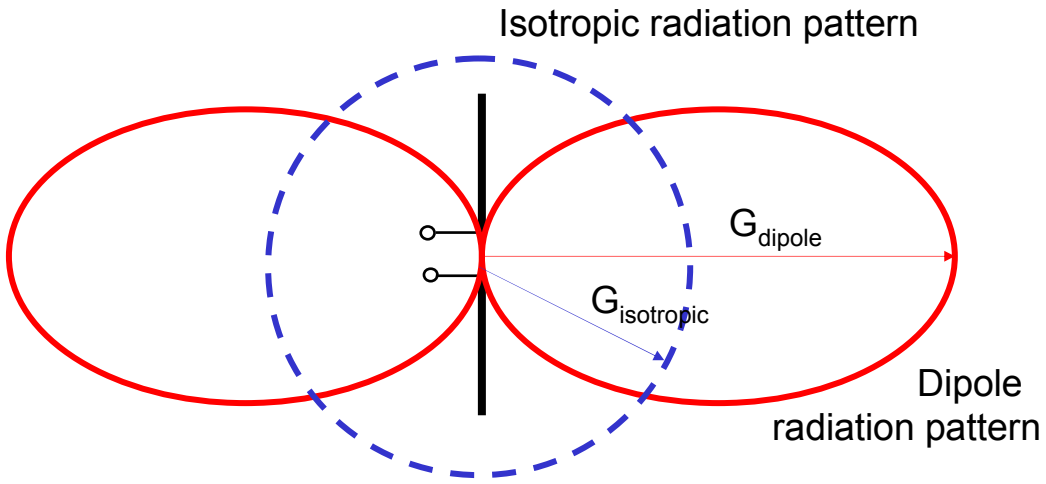




A (m)	B (m)
0.5	0.8
1.0	1.4
1.5	2.0
2.0	2.6
2.5	3.2
3.0	3.7

ERP and EIRP compared

Regulations expressed in EIRP (equivalent isotropic radiated power) are based on the spherical radiation pattern of an isotropic emitter



Real antennas such as dipoles, do not radiate uniformly in all directions (e.g. no power is radiated along the axis).

ERP power levels relate to the dipole antenna, and the relationship between the gain of an isotropic and a dipole antenna is given by:

$$P_{EIRP} = P_{ERP} \times 1.64$$

Thus the European limit of 2W ERP is equivalent to 3.28W EIRP (USA = 4W EIRP)

Antenna Gain

- To set your reader to the correct power level, one thing you will need to know is the gain of your antenna
  - Linear antennas express the gain in dBi (Isotropic)
  - Circular polarized antennas show the gain as dBiC

- In your calculations you will need to compensate for the lower output of a circular polarized antenna
  - This is done by subtracting 3 dBi from the indicated gain of the circular polarized antenna

$$\text{Gain (dBi)} = \text{dBiC} - 3 \text{ dBi}$$

  - So for a circular polarized antenna with gain 7.5 dBiC

$$\text{Gain (dBi)} = 7.5 - 3 = 4.5 \text{ dBi}$$

Antenna Feeder Cables

- Coax feeder cable selection is important to limit reductions in antenna output

Cable type	Attenuation @ 900 MHz		
	1m	10m	100m
RG8X (Belden 7808A)	0.23 db	2.3 dB	23.0 dB
LMR 240	0.25 dB	2.5 dB	24.9 dB
RG8X (Belden 9258)	0.35 dB	3.5 dB	35.0 dB
RG223 (Belden 9273)	0.46 dB	4.6 dB	46.0 dB
RG58 (Belden 82620	0.61 dB	6.1 dB	61.0 dB

Note: Always get the actual value from the manufacturer of your type of coax cable

- If you have long cable runs it is important to select a low loss coax
- The down side is that these cables are expensive and can be inflexible.
- Although we increase the output power to compensate for downlink losses, our return signal will still be reduced by coax losses.

Coax Cable Routing

- **To optimise a system, cable routing is important.**
  - Keep feeder cables as short as possible
  - Keep them all the same length, coil in a figure-of-eight if necessary.
  - On a portal, ideally position the reader centrally at the top

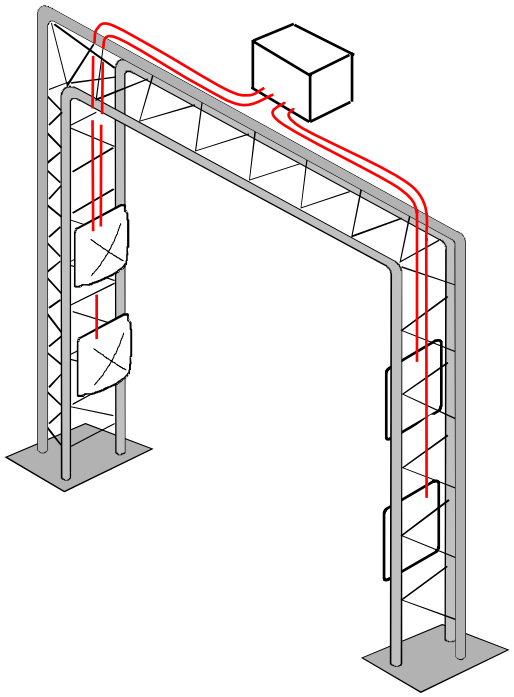


Figure-of-eight

Power Limits

- Reader radiated power limits are expressed in Watts or dBm

Region	Regulations	RF Power	Radiated Power
USA	FCC Part 15	1 W	4 W EIRP (36 dBm)
Europe	EN 300 220 EN 302 208		0.5 W ERP (29 dBm) 2 W ERP (35 dBm)

  - The decibel (dB) is the ratio between two power values and is defined as

$$dB = 10 \times \log(P_1/P_2)$$

  - For dBm the units for P_1 and P_2 are in milliwatts

e.g 4 Watts EIRP = $10 \times \log(4000/1) = 36$ dBm

Power Limits

- The table below gives the conversions between Watts and dBm

mW	dBm	mW	dBm	mW	dBm	mW	dBm
100	20.00	1400	31.46	2600	34.15	3800	35.80
300	24.77	1500	31.76	2700	34.31	3900	35.91
400	26.02	1600	32.04	2800	34.47	4000	36.00
500	27.00	1700	32.30	2900	34.62	4100	36.12
600	27.78	1800	32.55	3000	34.77	4200	36.23
700	28.45	1900	32.79	3100	34.91	4300	36.33
800	29.03	2000	33.01	3200	35.00	4400	36.43
900	29.54	2100	33.22	3300	35.18	4500	36.53
1000	30.00	2200	33.42	3400	35.31	4600	36.62
1100	30.41	2300	33.62	3500	35.44	4700	36.72
1200	30.79	2400	33.80	3600	35.56	4800	36.81
1300	31.14	2500	34.00	3700	35.68	4900	36.90

  - Marked in red are the European and North American limits

Setting the Reader Power

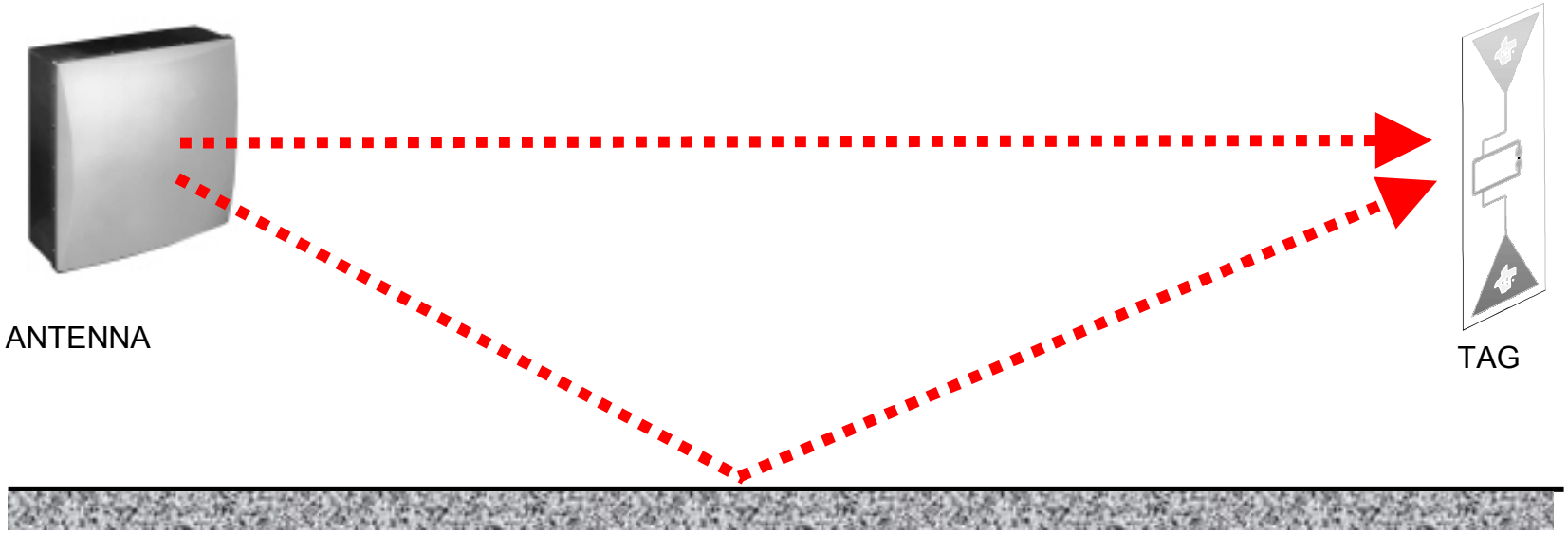
- To set your reader to the correct power level, you will need to know:
  - The legal limits in dBm (e.g. 29 dBm)
  - The antenna gain in dBi (e.g. 4.5 dBi)
  - The coax losses in dBm (e.g. 10 m × 0.5 = 5.0 dBm)
- The reader power is then calculated by:

  Reader Power (dBm) = Limit – Gain + Losses

  e.g. 29 dBm – 4.5 dBi + 5 dBm = 29.5 dBm (or ~900 mW)
- Your reader supplier will advise you how to configure your reader to achieve a particular output

UHF Signal Propagation

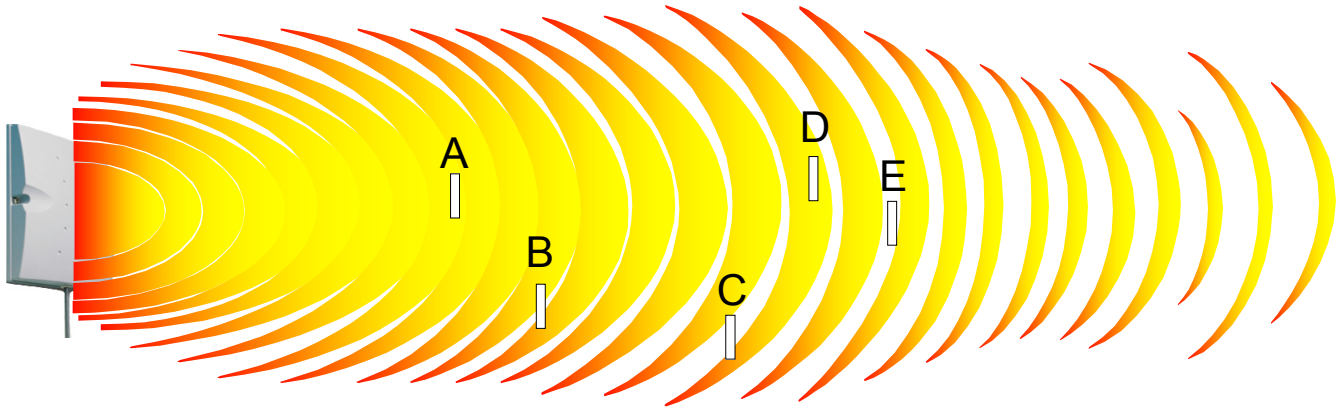
- At UHF frequencies multi-path RF waves, caused by reflections from the floor and other obstructions, may combine constructively or destructively.



  - When these signals are in-phase they combine to give a stronger signal but when out-of-phase, they cancel and create ‘reading holes’

UHF Signal Propagation

- Multi-path reflections from metal (reinforcing in floors/ dock levellers and other objects), cause nulls and peaks that get worse with distance from the antenna.



  - Labels A and D are in strong zones and will read.
  - Label B will read if its antenna is long enough to 'span the gap'
  - Label C and E will not read

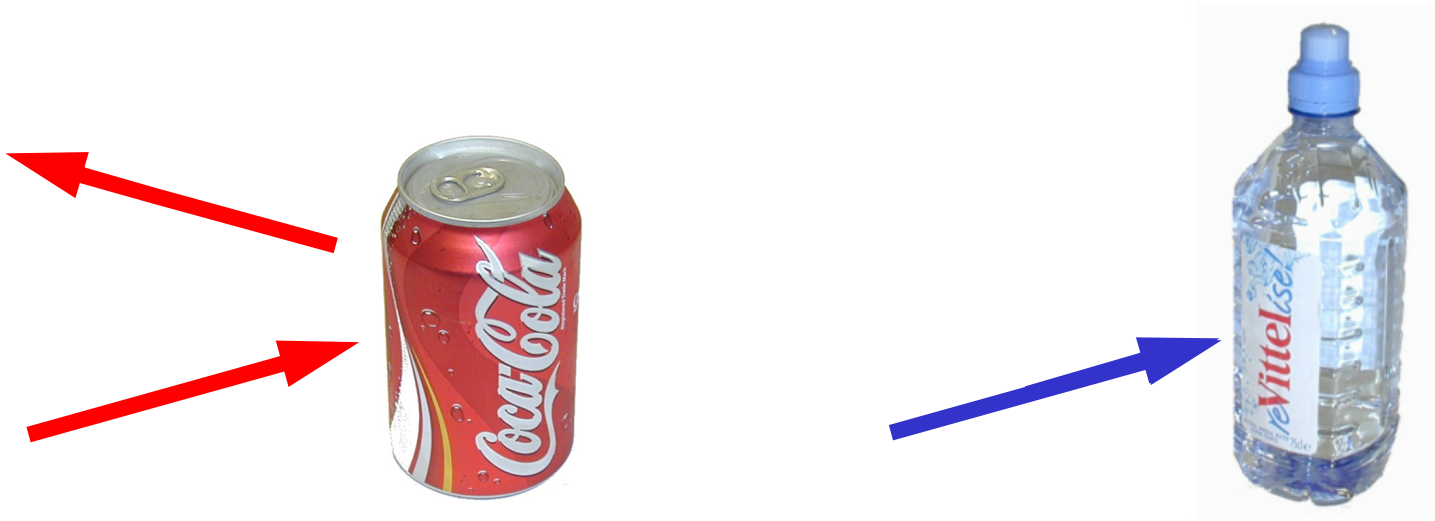
Avoiding Reading Holes

- Reading holes can be reduced in a number of ways

1. By removing metal from the reading area
   - If the reflections can be reduced so will the holes
   - This may not always be possible e.g. metal dock levellers
2. By using multiple antennas
   - This is the most common approach, with pairs of antennas orientated at slightly different angles.
   - Different antenna combinations can ensure tags in all positions are read
3. By movement of the label past the antenna
   - As the label moves it will cross the holes and be read at some point. The exact speed is a compromise between the number of labels and the bandwidth of the system. Because of Governmental regulation, readers are capable of reading more labels in the same time in the USA than is possible in Europe

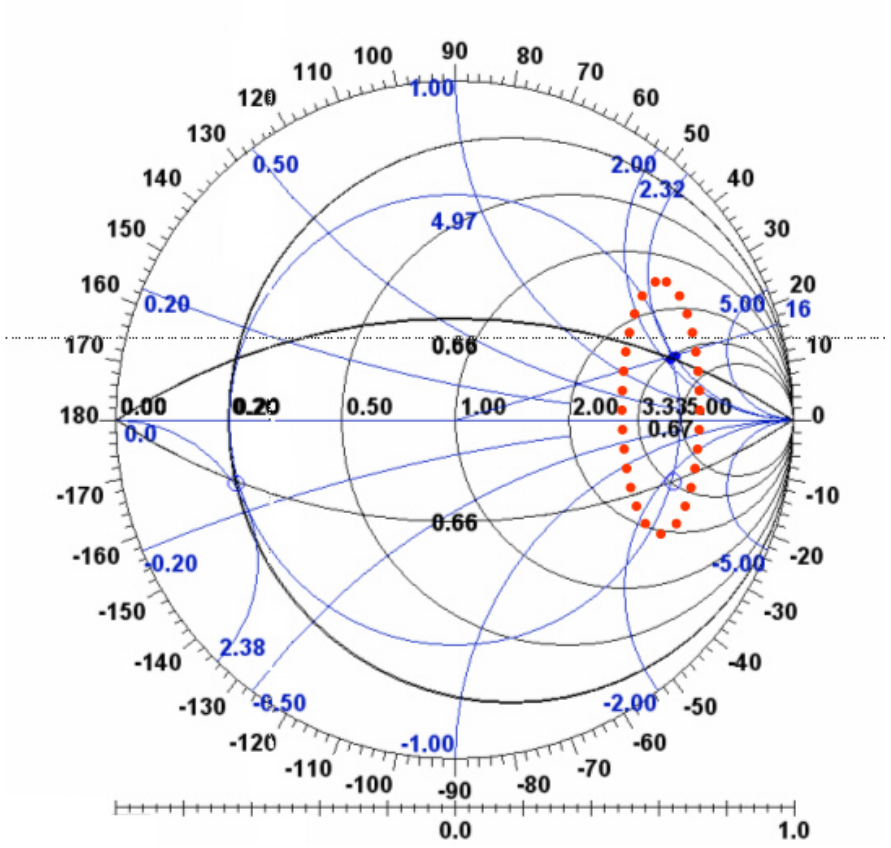
UHF Signal Attenuation

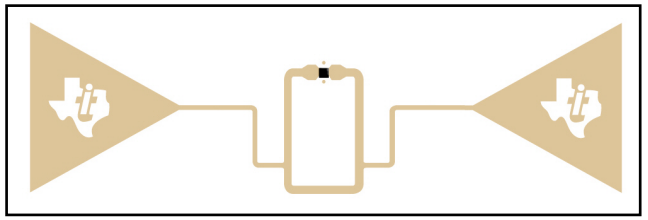
- At UHF frequencies, the material a label is attached to, can greatly affect that label's reading performance.
  - **All** materials reduce the power of the RF signal to some extent but *metal* and *liquids* can cause particular problems
    - Metals reflect the signal
    - Liquids absorb the signal.



Inlay Selection

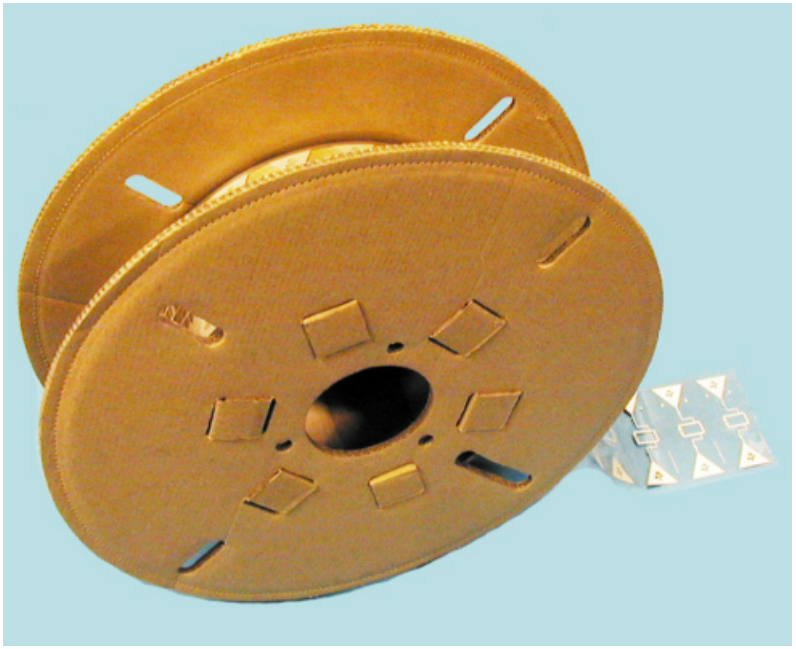
- By careful analysis of inlay performance on different materials, Texas Instruments has created its “Dallas” inlay – designed for integrating into labels for most common products packaging.





Inlay Selection

- Reels of 10,000 UHF EPC Gen2 /ISO 18000-6C conformant inlays are available to partner label converters



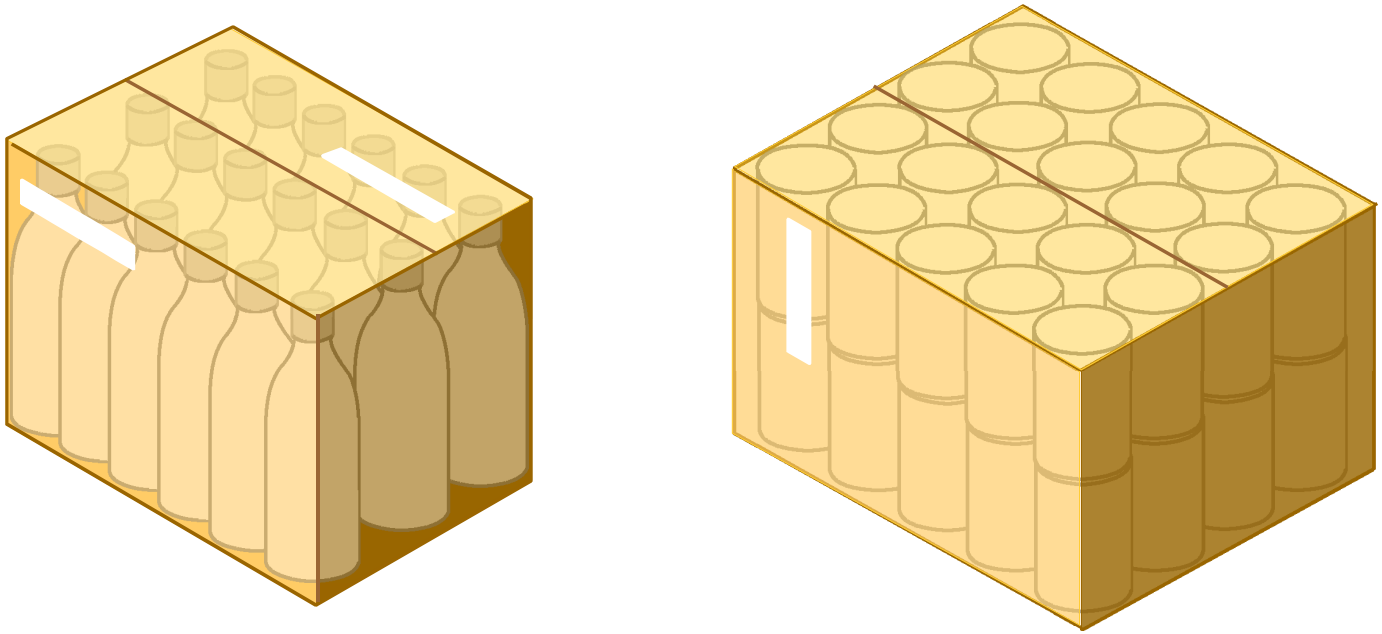
Part Numbers:

RX-UHF-00C01-03 (Inlays)

RX-UHF-00C00-00 (Chipless)

Label Placement

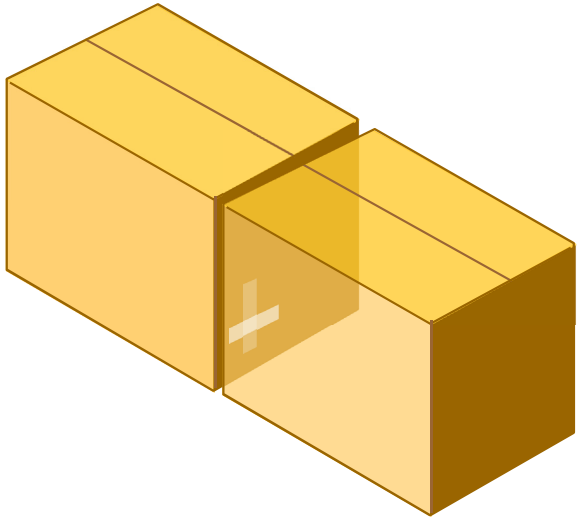
- Careful label placement is another obvious help in overcoming these issues
  - Choose a site for the label where an internal ‘airgap’ exists



  - In the drawings above, the labels are shown in positions where an airgap exists and the internal product is furthest away.

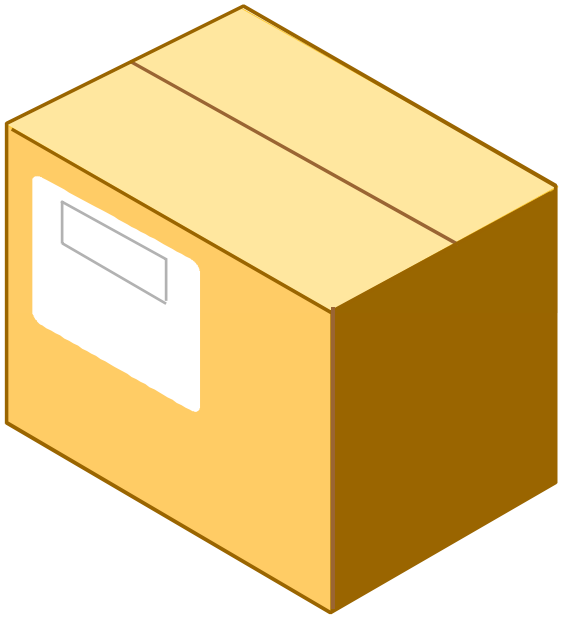
Label Placement

- It may not be possible to read labels on cartons in the center of a pallet.
  - It depends on a number of factors:
    - Output power of the reader antennas
    - The distance from the antennas
    - The material in the cartons
  - If at all possible, position the labels on the outside of the pallet load.
  - One situation that **must** be avoided is overlapping labels
    - Labels that overlap are the same as placing each label close to metal. They de-tune each other and performance is lost.



Printed Antennas

- Label placement will need to be designed-in if you intend using straps together with an antenna that is printed on the carton
  - You will need to work closely with the label manufacturer to determine the optimum location for each product.
  - This will also impact on the layout of the other printed information.



Limiting Interference

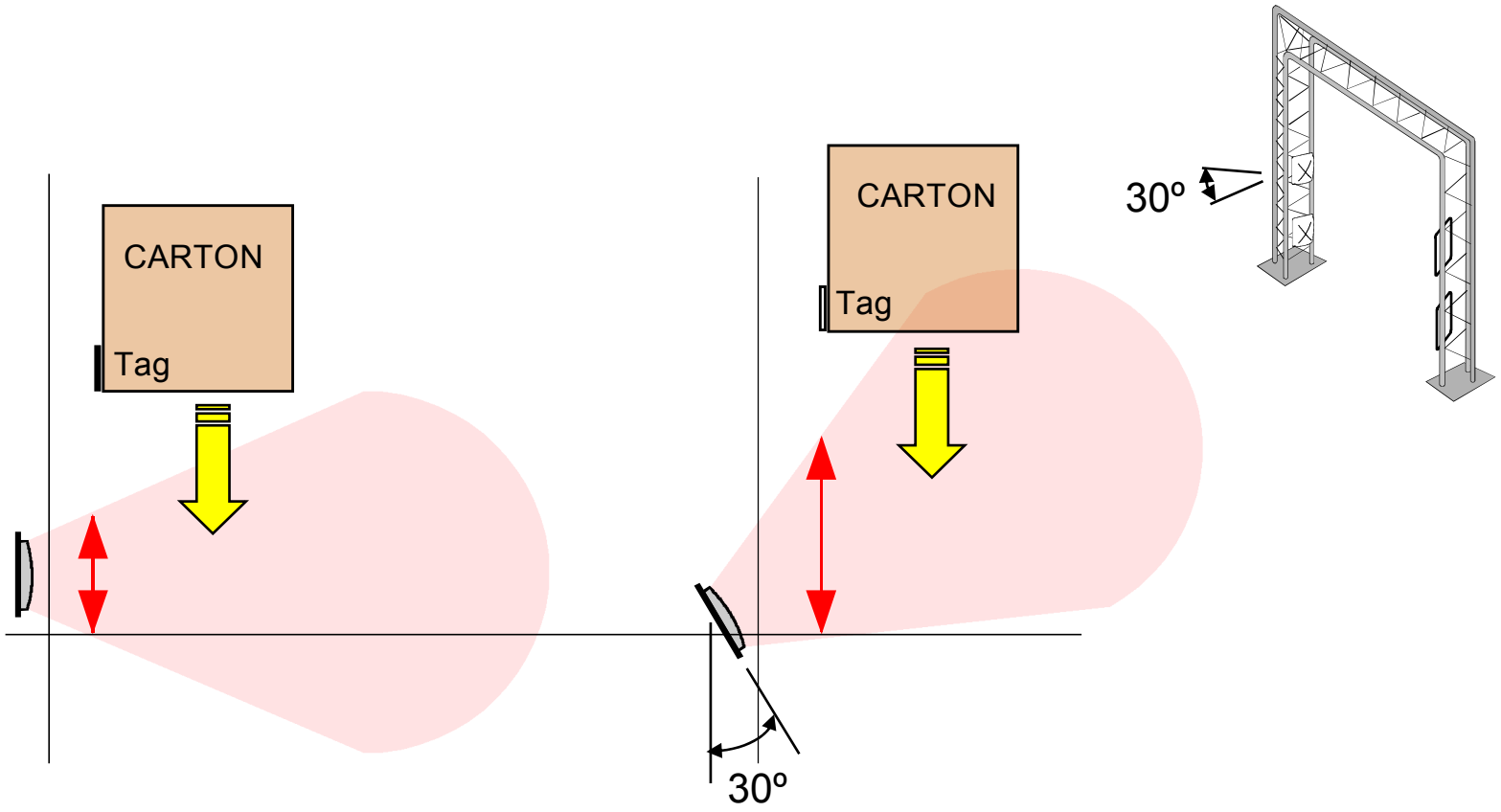
- Multiple Readers operating in the same environment may interfere with one another.
  - A number of techniques can help limit these unwanted effects:
    - Use photo-cell triggering to initiate reading - don't have the reader transmitting all the time
    - Reduce the power
    - Reduce the downlink rate (40 kbs)
    - Use wired synchronisation (if your readers support this option)
    - Shield between reading systems with absorptive material (Metal could make the problem worse)

Reading Rates

- Read speed will depend on the country regulations
  - In Europe, because the bandwidth is much less, reading rates are slower. Where there are many labels on a pallet load, then 100% read rates at normal forklift speeds may not be possible.
  - This is especially true when many antennas are multiplexed

Increasing the Read Time

- One way to increase the time a tag is in the RF field is by positioning antennas at a slight angle (20º – 30º)



Trialling

- If your company is required to tag case and pallet level product:
  - It is important to understand the reading system at the distribution center
  - And send trial loads to determine the best label placement locations
  - Several test centres are available to test cases with UHF labels

Acknowledgement to Dept. of Defense