

A STUDY OF ANTENNAS & READERS FOR SUPERMARKET SHELVES

PETER H. COLE



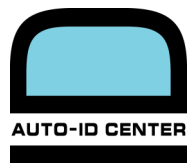
OUTLINE

- Label operating principles
- Electromagnetic fields
- Shelf antennas and readers
- Its all about electromagnetic fields
- Its also about regulations
- Need consider available frequencies
- Also later consider reader architecture
- Experiments
- Two types of shelves
- Two types of label
- Two types of reader
- Conclusions



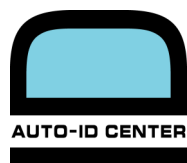
LABEL OPERATING PRINCIPLES

- Labels are in practice passive
- Replies are modulated backscatter
- Modulation is of a sub-carrier
- Sub-carrier frequency \ll carrier frequency
- Manufacturing technology is cmos
- Keeps tag operating power small
- Modulation may be phase or frequency
- Carriers are in ISM bands
- Powering and reply is by electromagnetic fields



So we study electromagnetic fields

Yuk



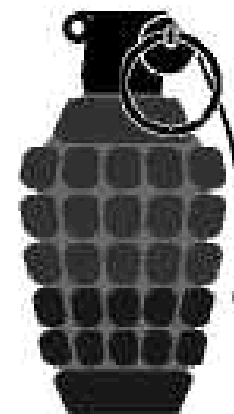
THE BASICS

$$\nabla \times \mathbf{E} = - \frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

$$\nabla \cdot \mathbf{D} = \rho$$

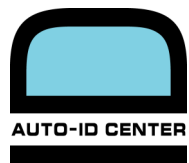
$$\nabla \cdot \mathbf{B} = 0$$



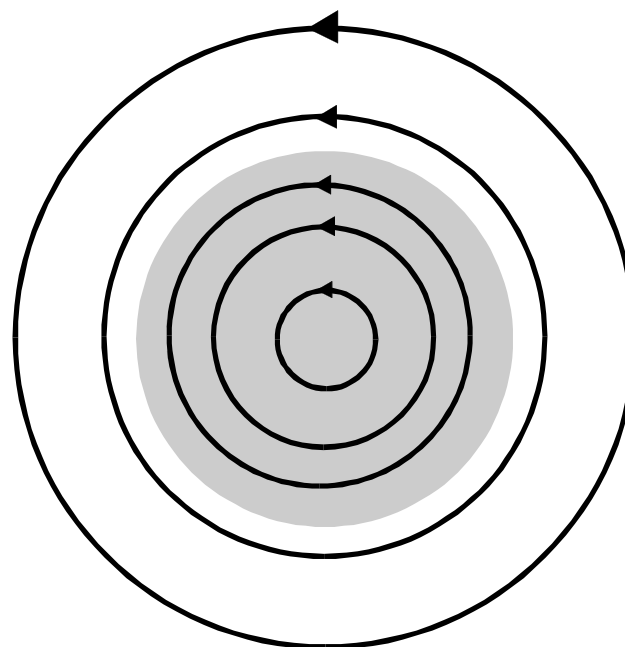
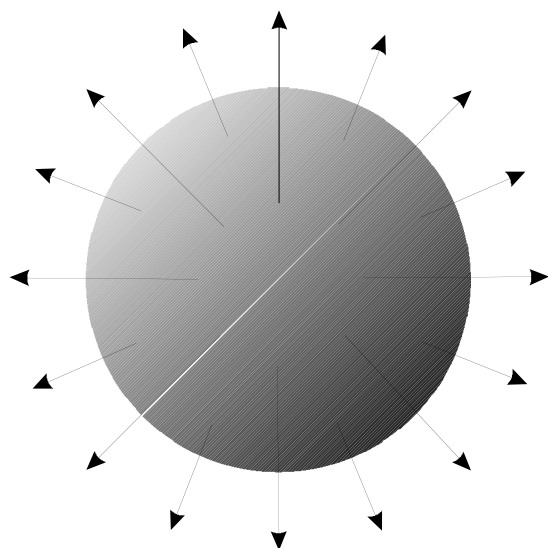
Source

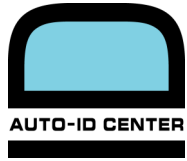


Vortex



SOURCE AND VORTEX FIELDS



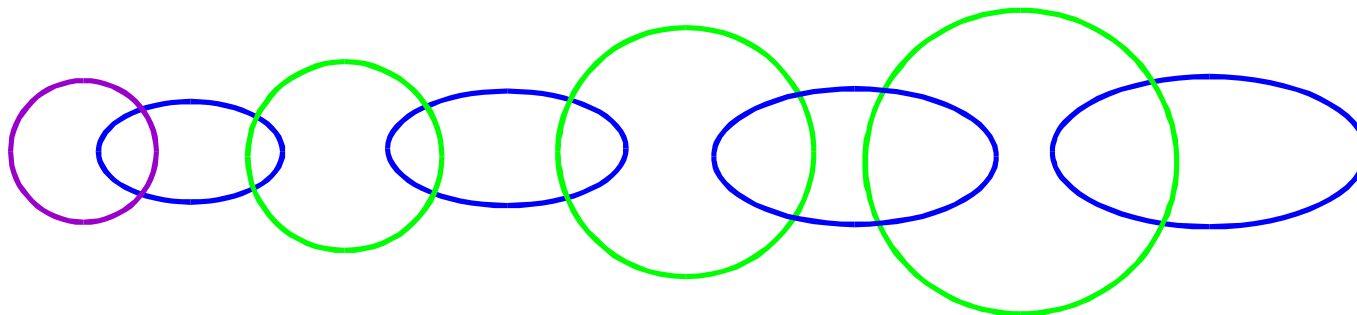


ELECTROMAGNETIC PROPAGATION

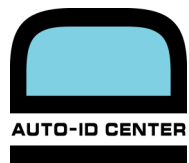
Electric current creates a vortex of magnetic field

Magnetic field creates a vortex of electric field

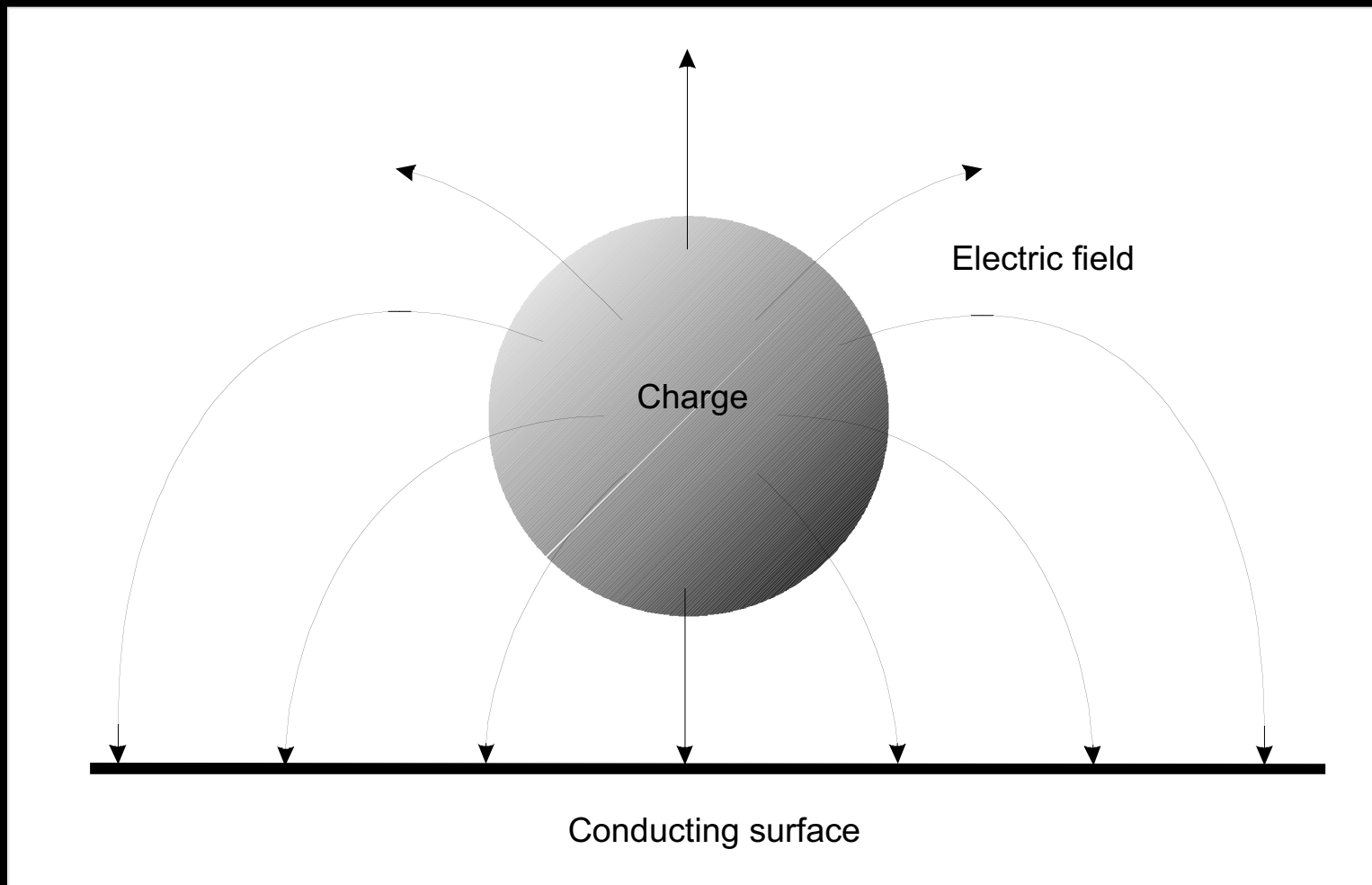
Electric field creates a vortex of magnetic field



Propagation

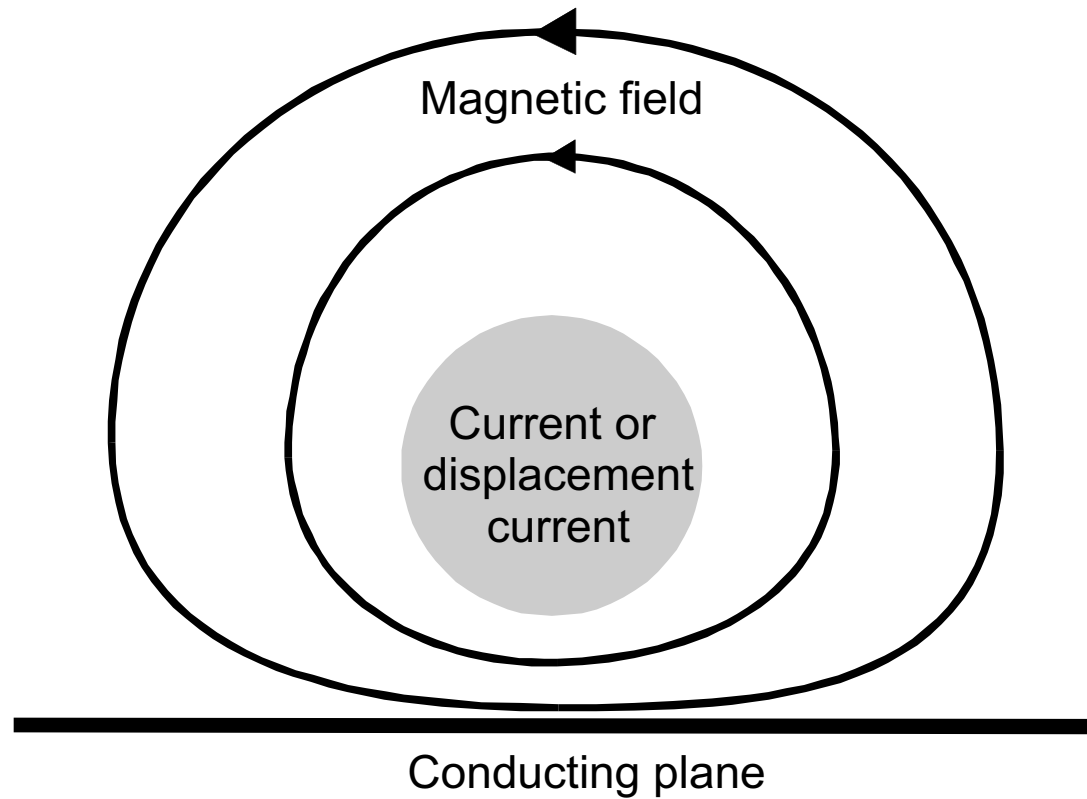


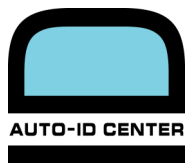
BOUNDARY CONDITION: ELECTRIC FIELD





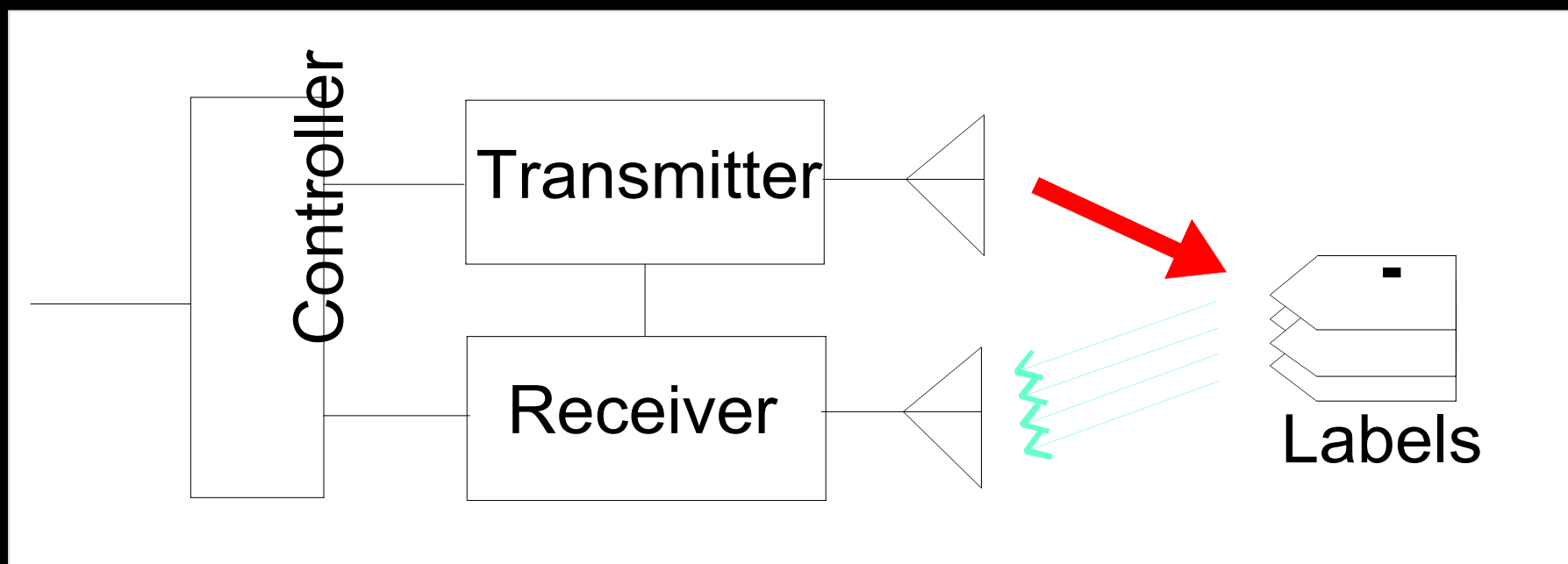
BOUNDARY CONDITION: MAGNETIC FIELD





LABEL READING ILLUSTRATION

- Multiple labels to be read
- Strong interrogation signal; weak reply
- Impact on system, label and reader design
- Practical frequencies are 13.56 MHz (HF)
- and 800-930 MHz (UHF)



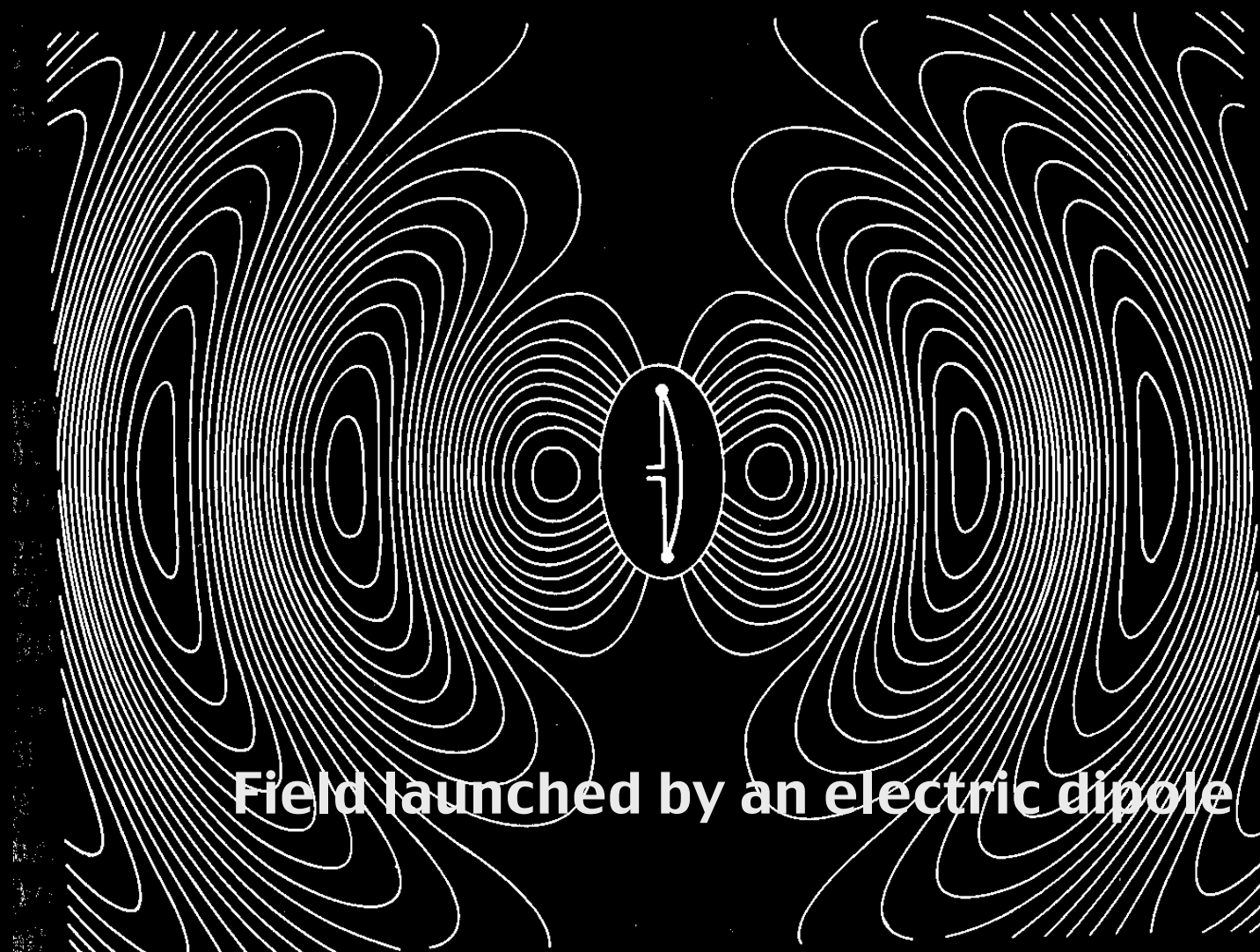


NEAR AND FAR FIELDS: SUMMARY

- The field near the antenna provides **energy storage**
Measure is $\omega\mu_0|H|^2 \text{ VA m}^{-3}$
- The field far from the antenna provides **energy propagation**
Measure is $\eta|H|^2 \text{ W m}^{-2}$
- Wavelength λ is always $= c/f$; $c = 300 \text{ Mm/s}$
- Examples: 13.56 MHz, 22m; 915 MHz, 328 mm
- Near-far boundary is at $\lambda/(2\pi)$ i.e. 3.5 m or 50 mm
- HF systems operate in near field; UHF operate in far field
- In near field, reactive power density drops off as r^{-6}
- In far field, power density drops off as r^{-2}

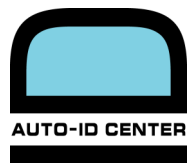


NEAR AND FAR ELECTRIC FIELD

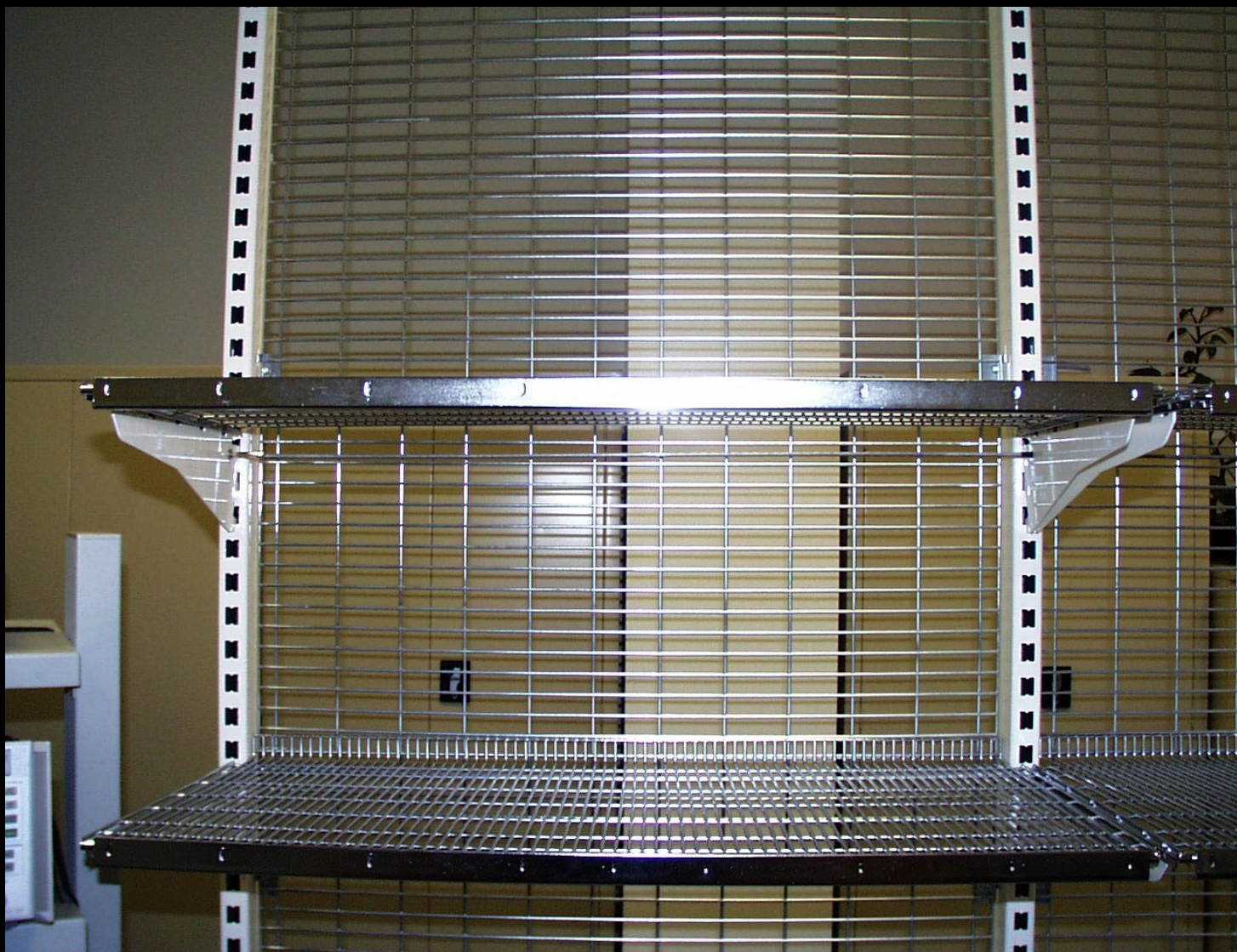


Field launched by an electric dipole

CONFIDENTIAL - FOR AUTO_ID SPONSORS ONLY



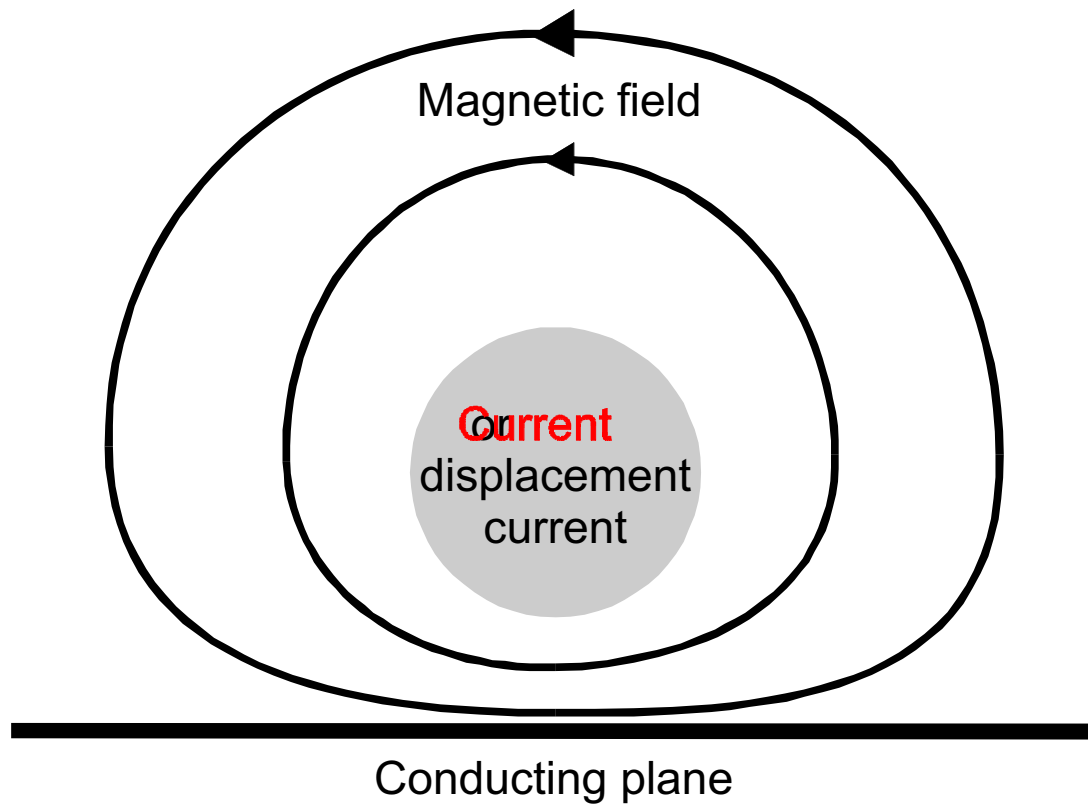
A SUPERMARKET SHELF



CONFIDENTIAL - FOR AUTO_ID SPONSORS ONLY



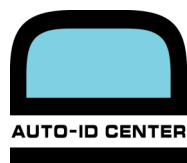
MAGNETIC FIELD BOUNDARY CONDITION



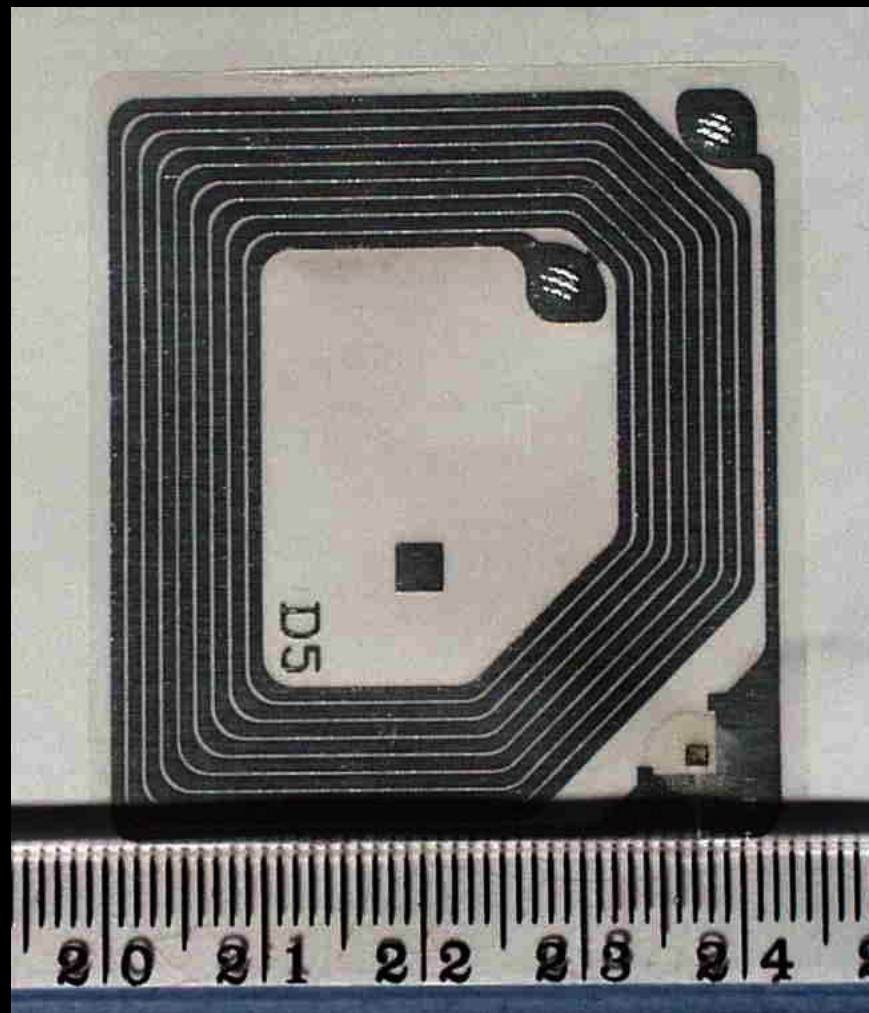


USEFUL ELECTRIC AND MAGNETIC FIELDS

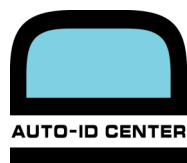
- Magnetic (useful)
 - Better penetration
 - But is dipolar in nature (power density drops off as r^{-6})
 - In practice more common than electric
- Electric (not so useful)
 - Can be monopolar (power density drops off as r^{-4})
 - But is easily stopped by mildly conducting media
- Electromagnetic (useful)
 - Far field involves an equal mixture of electric and magnetic fields
 - Power density drops off as r^{-2}
 - Label antennas can couple more to one than another



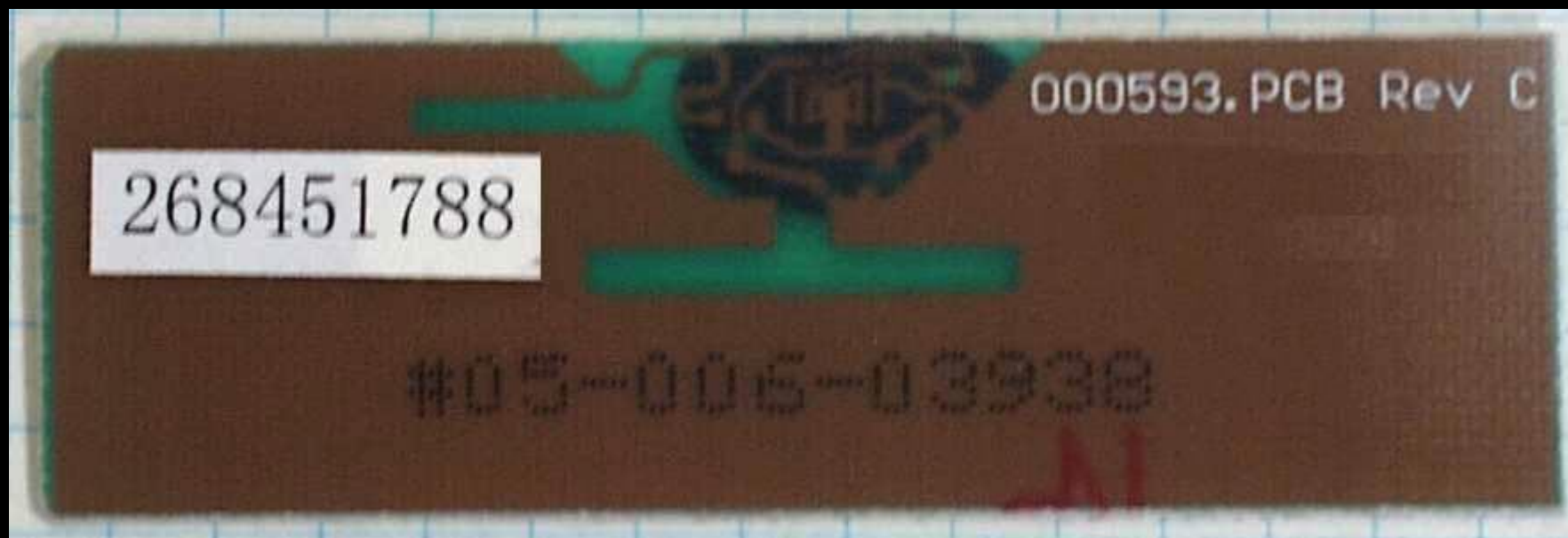
AN EARLY MODEL HF LABEL

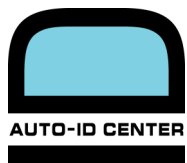


CONFIDENTIAL - FOR AUTO_ID SPONSORS ONLY

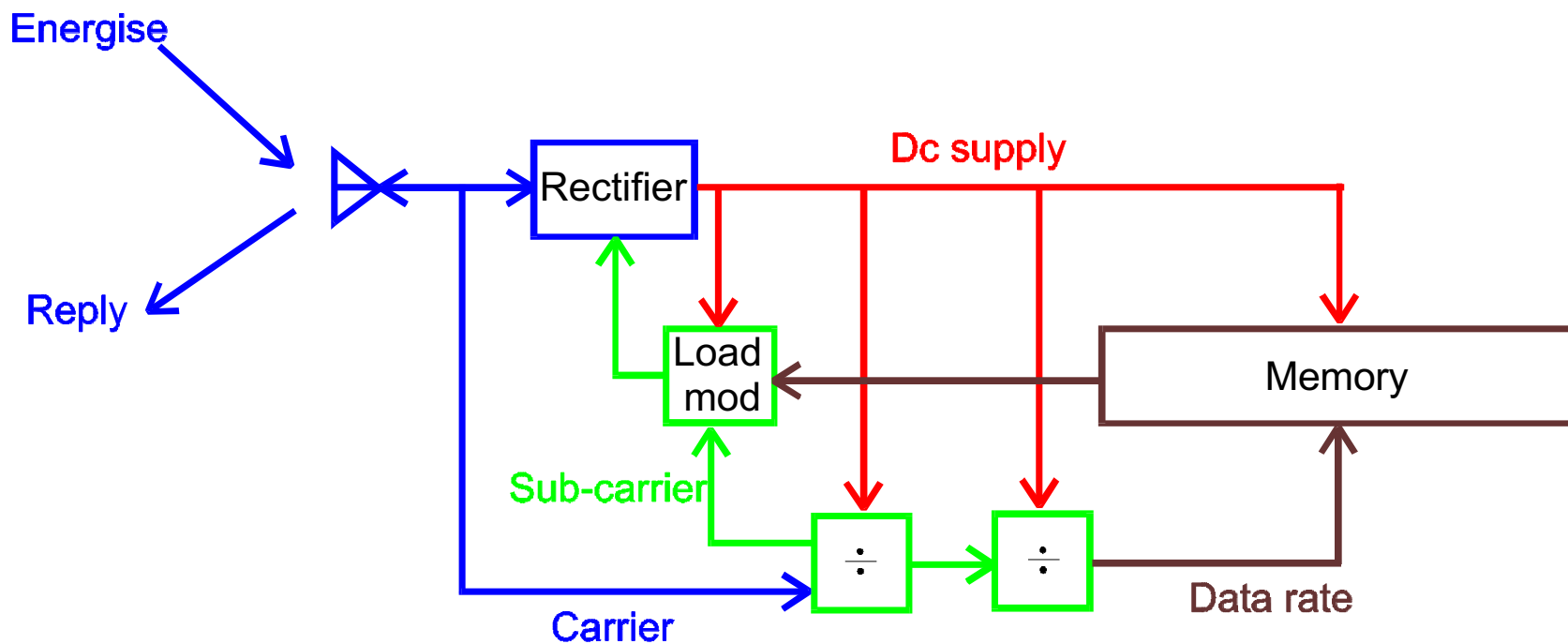


AN EARLY MODEL UHF LABEL





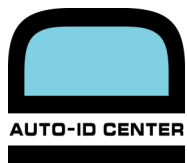
A COMMON LABEL ARCHITECTURE



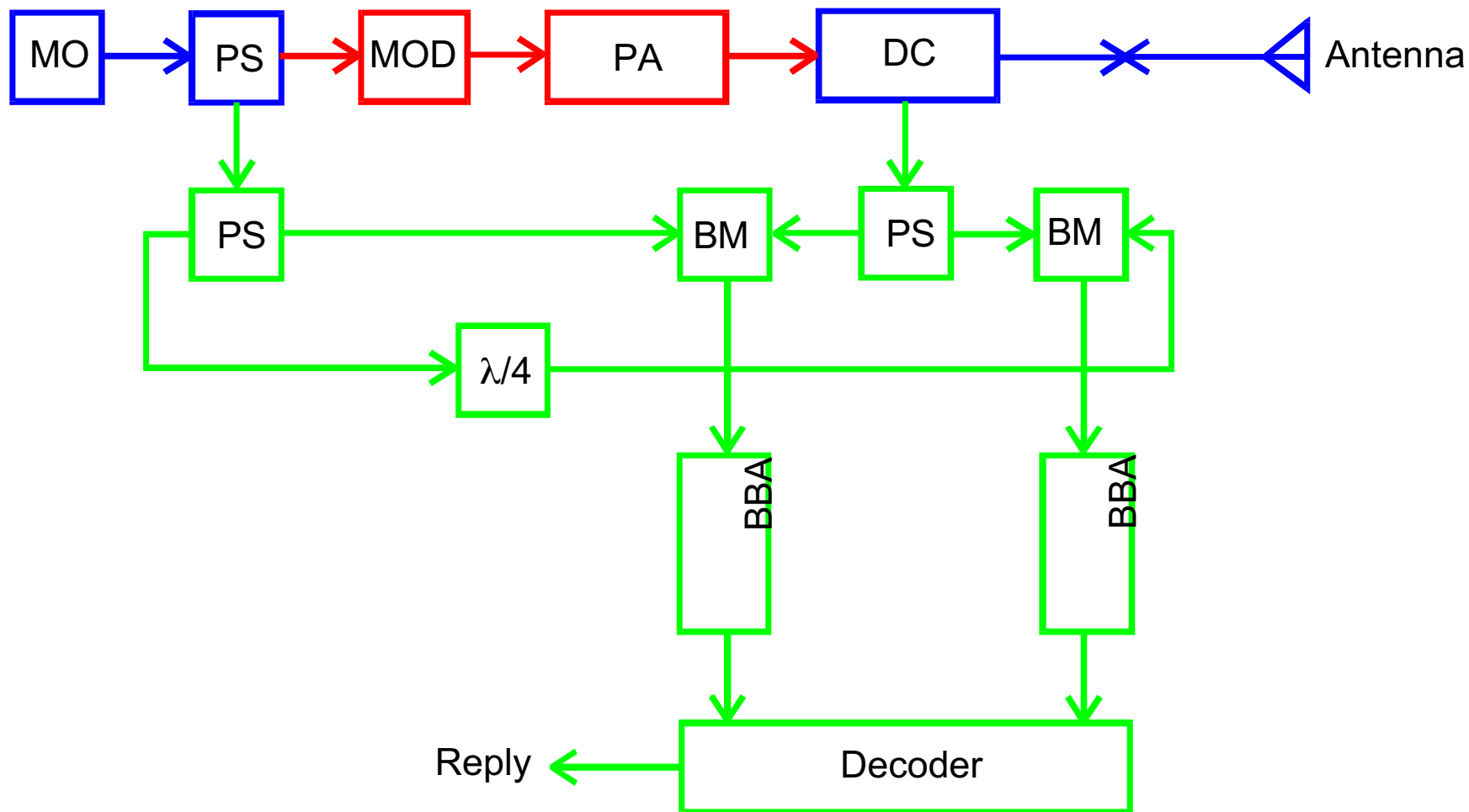


A COMMON READER ARCHITECTURE

- CW transmitter and homodyne receiver
- Received signal mixed to base band with transmitted signal acting as local oscillator
- Null position problem when replies are 90 degrees out of phase with transmitter
- Solution is use in-phase and quadrature receiver channels
- Can be combined or can have separate decoding
- At HF, can use single channel and careful phase adjustment



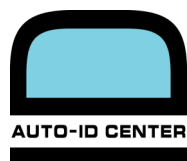
HOMODYNE READER ARCHITECTURE



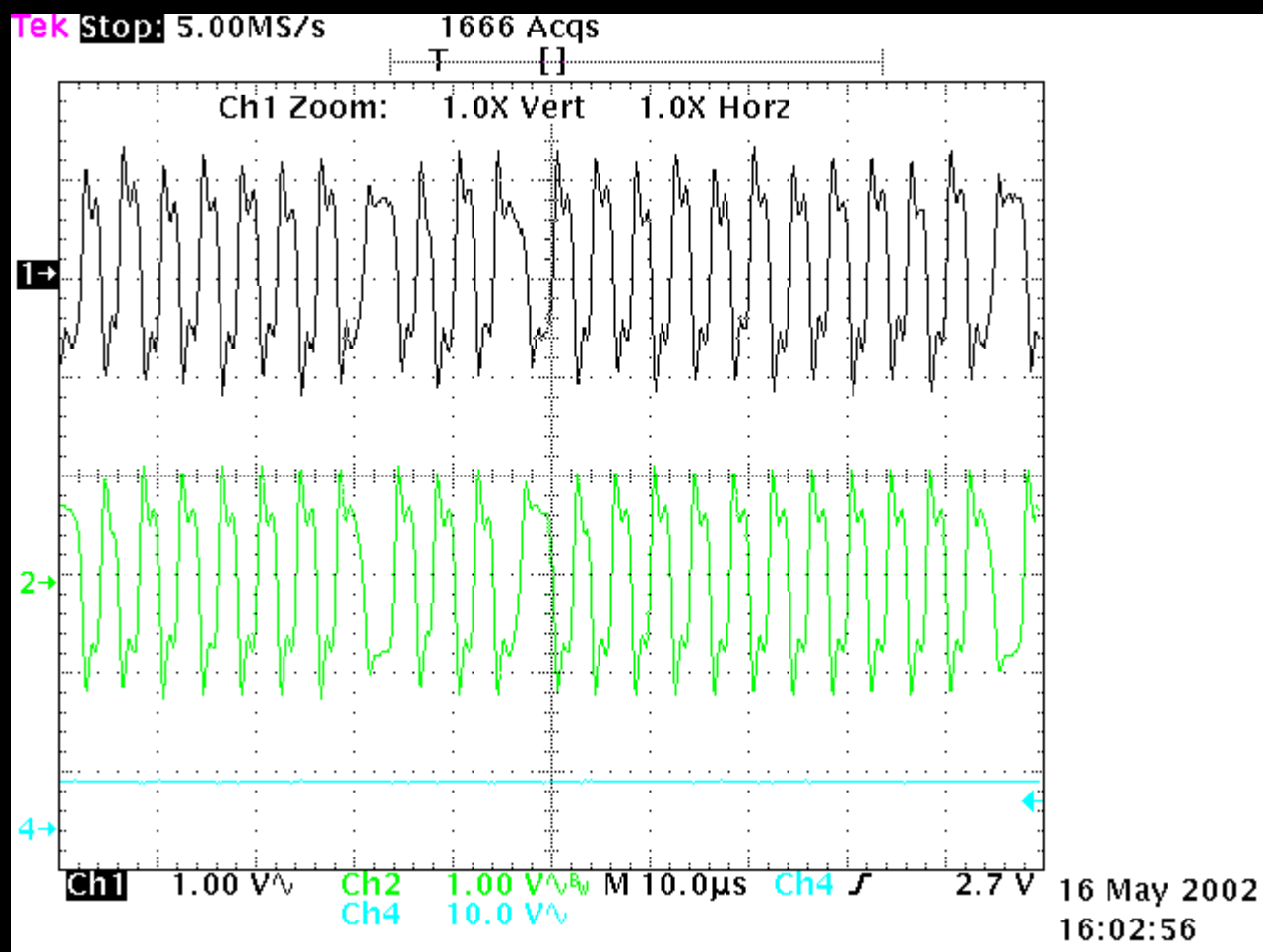


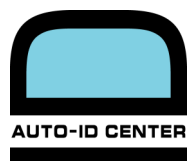
LABELLING SYSTEMS EMPLOYED

- 915 MHz system
 - Pulsed single read operation
 - Bi-phase modulation
 - Average output power 17 mW
 - Peak power 580 mW
- 13.56 MHz system
 - Continuous multi read operation
 - Frequency modulation
 - Output power (to antenna losses) 800 mW

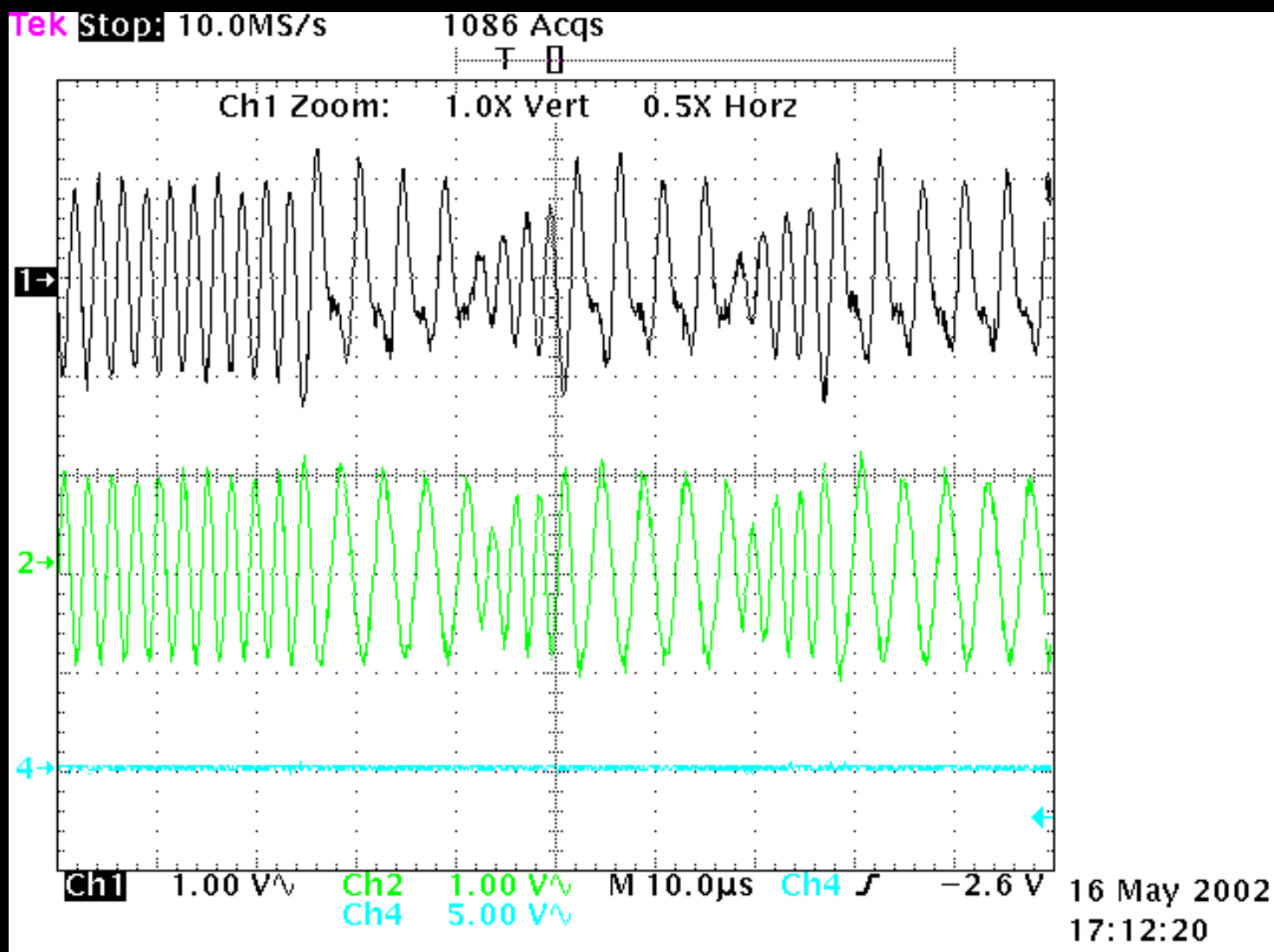


BASEBAND SIGNALS - PM





BASEBAND SIGNALS - FM

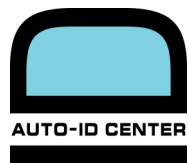


CONFIDENTIAL - FOR AUTO_ID SPONSORS ONLY



GENERAL READER LIMITATIONS

- Transmitter phase noise
- Multipath propagation
- Shaping of fields for good coupling



A COMMON SHELF STRUCTURE

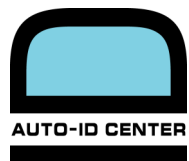


CONFIDENTIAL - FOR AUTO_ID SPONSORS ONLY



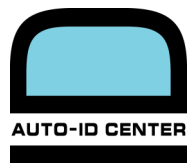
SHELF STACKING POLICIES

- Close packing of products
- Shelf vertical spacing to suit product size
- Uniform 1800 mm bays, 900 mm back support
- No stacking of products which will not survive falls to ground
- Solid metal shelves reasonably common
- Sloping sometimes to improve presentation
- Hooks for hung products
- Metal mesh backing



UHF READER EXPERIMENTS

CONFIDENTIAL - FOR AUTO_ID SPONSORS ONLY



A SIMPLE UHF WIRE ANTENNA

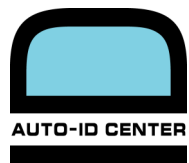


CONFIDENTIAL - FOR AUTO_ID SPONSORS ONLY



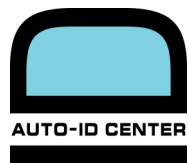
RESULTS AND CONSEQUENCES

- Multipath propagation (as expected)
- Prominent field nulls
- Non-optimum product illumination
- So changed to patch antenna
slung under the shelf above
- Circularly polarised 5 dB gain patch
- Uniform reading over full 900 mm bay
- Noting packing policies, the results give great confidence for most products



HF READER EXPERIMENTS

CONFIDENTIAL - FOR AUTO_ID SPONSORS ONLY



EXPERIMENTAL HF SHELF STRUCTURE

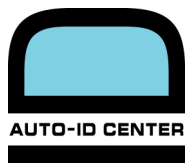


CONFIDENTIAL - FOR AUTO_ID SPONSORS ONLY

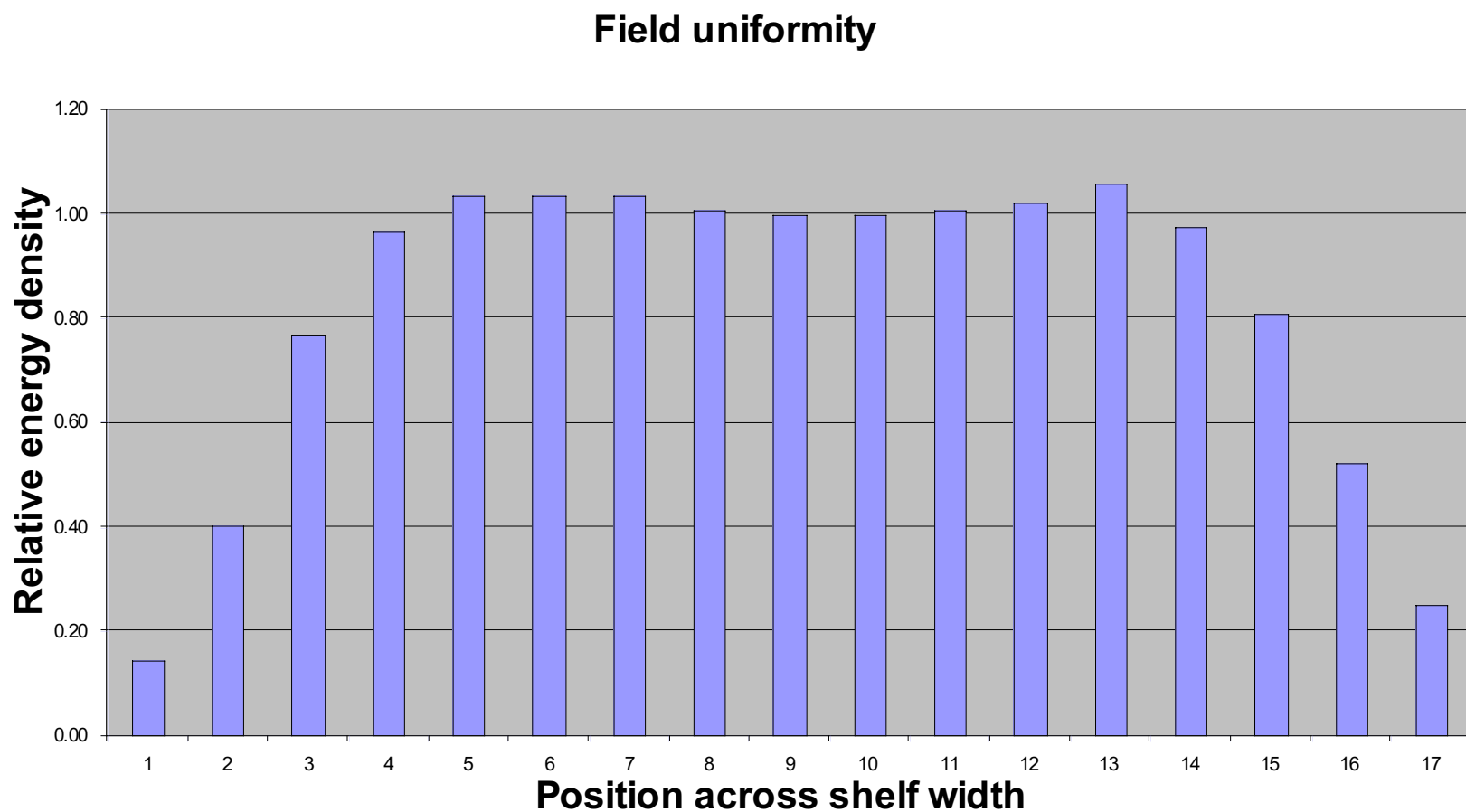


RESULTS

- Read above and below shelf to half bay height
- Field uniformity illustrated next



HF FIELD UNIFORMITY





CONCLUSIONS

- Expectations confirmed and enhanced
- Adequate sensitivity at both both frequencies (HF and UHF) even with old model labels
- Little evidence of UHF phase noise
- Good coverage for UHF patch antenna
- Good coverage for HF loop antenna
- Good uniformity for HF systems
- Overall very encouraging



ACKNOWLEDGEMENTS

- Benham Jamali
- Stephen Guest
- Ian Linke
- David Hall