ESPTR: Radar Basics

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Prototype


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Electromagnetic version

1865 James Clerk Maxwell - theory of electromagnetic waves

1886 Heinrich Hertz - experimental proof

1904 Christian Hülsmeyer - *Telemobiloskop*: ship collision avoidance apparatus, patented in Germany and UK; demonstration at the Rhine river in Cologne, DE.

...

1939-1945 Home Chain and other installations

Radar equation

Transmit-reflect-receive-detect

Received power: radar *range* equation

$$P_r = \frac{P_t G_t A_r \sigma F^4}{(4\pi)^2 R_t^2 R_r^2}$$

- P_t transmitter power
- G_t gain of the transmitting antenna
- A_r effective aperture (area) of the receiving antenna
- σ radar cross section, or scattering coefficient, of the target
- F pattern propagation factor
- R_t distance from the transmitter to the target
- R_r distance from the target to the receiver.

2x range $\longrightarrow 2^4 = 16$x power needed ...

Signal model

Transmit:

$$x_T(t) = A_T(t)e^{j\phi_T(t)}$$

Receive:

$$x_R(t) = A_T(t - R(t)/c)e^{j\phi_T(t-R(t)/c)}$$

simple case: $\phi_T(t) = \omega t + \phi_M(t)$, $R(t) = R_0 + vt$

$$x_R(t) = A_T(t - R_0/c - vt/c)e^{j(\omega(t-R_0/c-vt/c)+\phi_M(t-R_0/c-vt/c))}$$

$$x_R(t) = A_T(t-R_0/c-vt/c)e^{j(\omega t)}e^{-j\omega(R_0/c)}e^{-j\omega vt/c}e^{j\phi_M(R_0/c+vt/c)}$$

$$x_R(t) = A_T(t-R_0/c-vt/c)e^{j\phi_M(R_0/c+vt/c)}\ e^{j(\omega t)}e^{-j\omega(R_0/c)}e^{-j\omega vt/c}$$

Detection

Maximize P_d (detection), keep P_{fa} (false alarm) low.
The threshold set above:

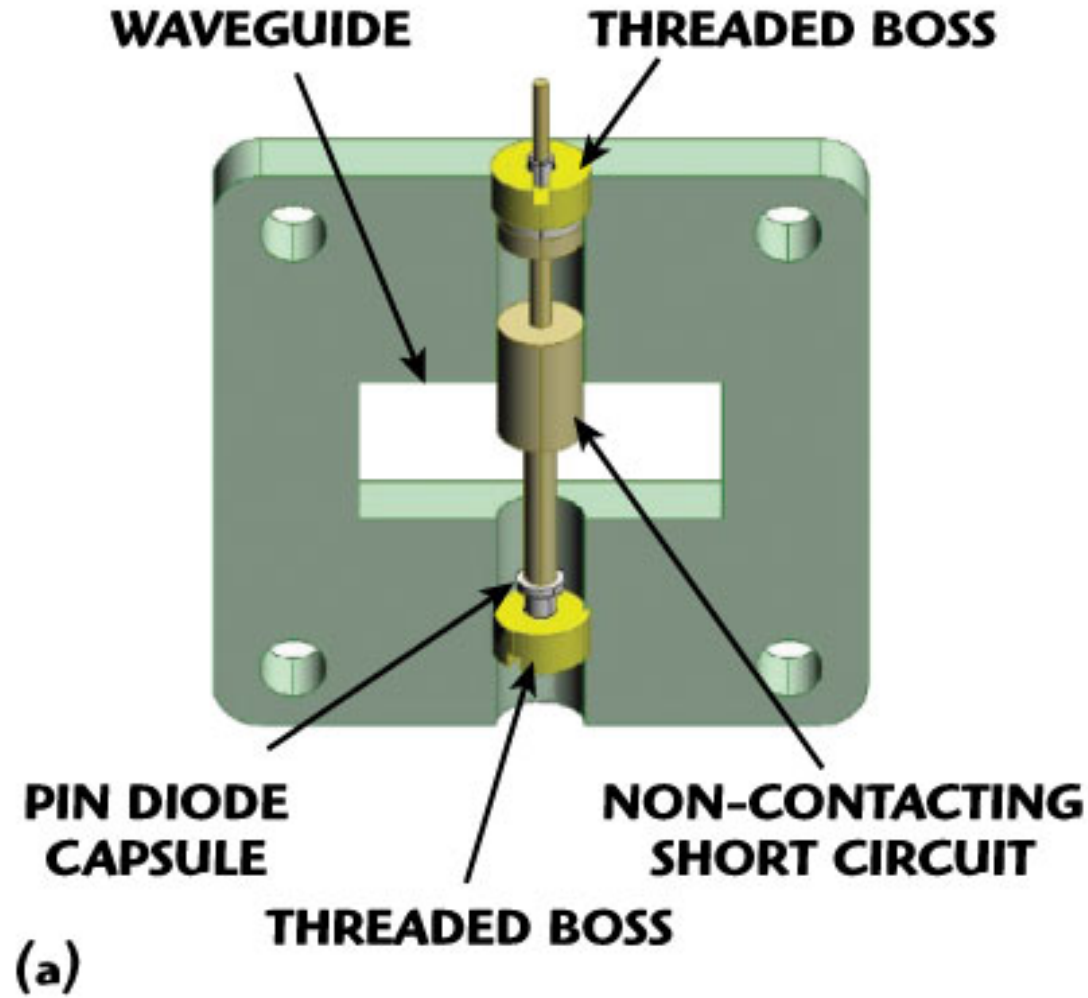
- Noise (thermal etc)
- Clutter (unwanted echoes)
- Multipath
- Jamming (intentionally malicoius transmitters)
- Interferences (other equipment, e.g. other radars)

Improvements: matched filter (S↑), interference cancellation (C↓)
Typical: SNR $\approx$ 13 dB
Adaptation: CFAR

Range measurement

$\longrightarrow$signal delay measurement

- Max *unambiguous* range limited by modulation period
- Min range limited by transmit signal entering the receiver
  - Antenna separation
  - T/R switch + receiver safety (ionised gas + pin diode)


WAVEGUIDE
THREADED BOSS
PIN DIODE CAPSULE
NON-CONTACTING SHORT CIRCUIT
THREADED BOSS
(a)
LIMITED RF OUTPUT

Velocity measurement

$\longrightarrow$Doppler shift measurement

$$x_R(t) = A_T(t - R_0/c - vt/c)e^{j\phi_M(R_0/c + vt/c)}\ e^{j(\omega t)}e^{-j\omega(R_0/c)}e^{-j\omega vt/c}$$

- Min velocity: ground/meteo clutter
- Max velocity (frequency): (inverse of) modulation period

Angle measurement

- azimuth
- elevation

Methods

- Scanning: mechanical, electronic
- Monopulse techniques (multielement antenna)
  - Power ratio
  - Sigma-Delta (power)
  - Phased arrays