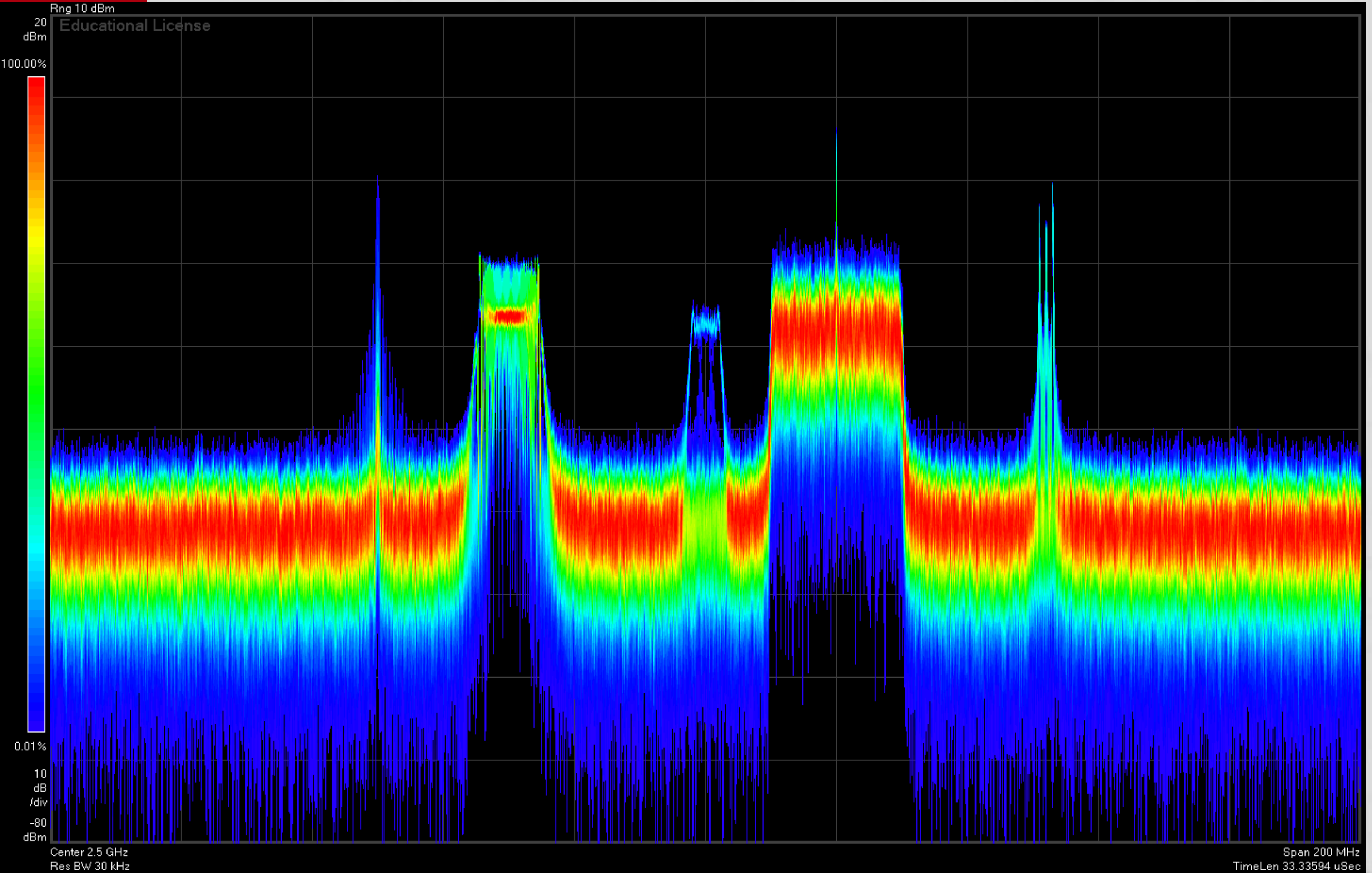
RF Stealth and Countermeasures

Short Course on Radar and Electronic Warfare

Kyle Davidson

The Threat



Rng 10 dBm
20 dBm
100.00%
Educational License
0.01%
10 dB /div
-80 dBm
Center 2.5 GHz
Res BW 30 kHz
Span 200 MHz
TimeLen 33.33594 uSec

27 August 1941 – Robert Watt

‘The simplest theoretical way of matching an aircraft to free space is to envelop it in a resistive skin whose surface-resistivity is 377 ohms, and to maintain an air gap between skin and aircraft of a quarter of a wavelength.

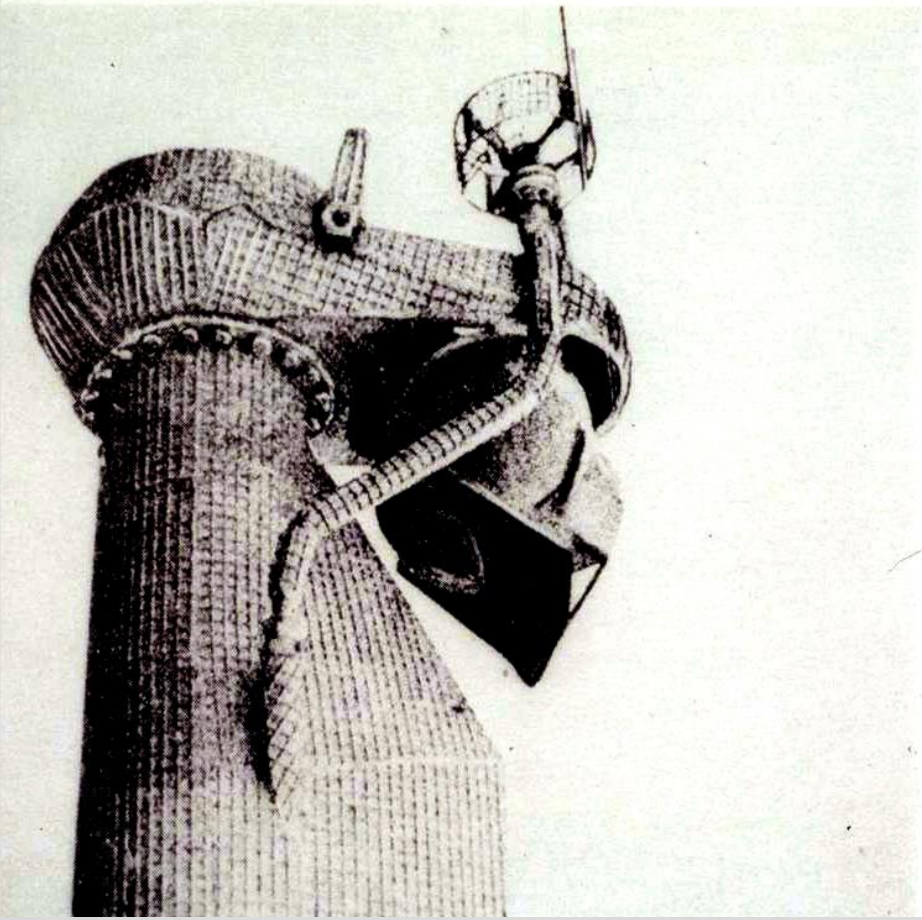
The gap between skin and aircraft may be considerably reduced by filling it with a medium in which the wavelength is less than in free space.

To obtain a large bandwidth we need to use a medium of low conductivity with a high ratio of permeability to dielectric constant. If this ratio is 4, the intrinsic resistance of the medium is

$$R = \sqrt{4} \times 377\ \Omega = 750\ \Omega$$

It is concluded that there is a real scientific possibility of camouflaging an aircraft over a limited frequency-range at centimetre wavelengths. How far large-scale use of such camouflaging may be feasible or useful is for others to decide.’

Radar Absorbing Material



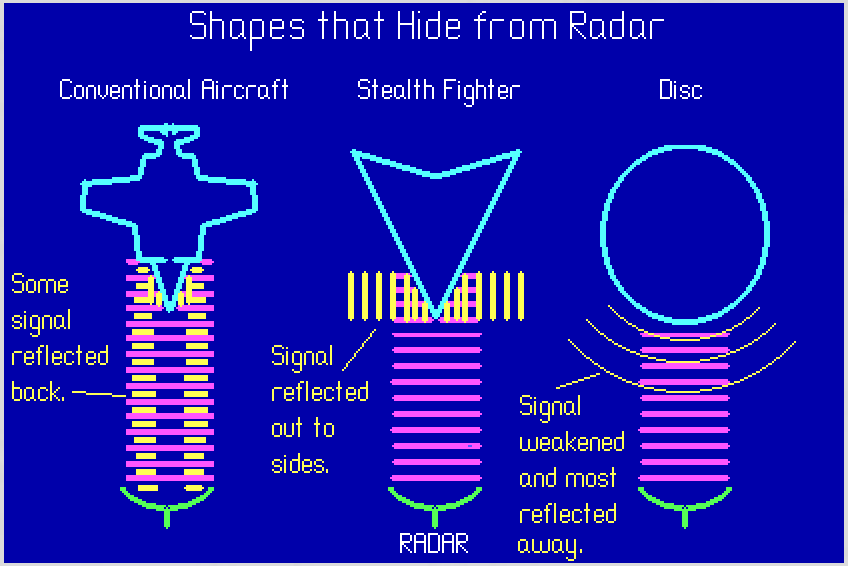
A Schnorkel tube covered with 'Sumpf'. This reduced radar returns to some extent but it soon became detached from the U-boat's structure by wave action, and salt deposits reduced its electrical effectiveness. The small dipole is the aerial for Tunis; it gave a good echo to 3-cm radars.

Stealth

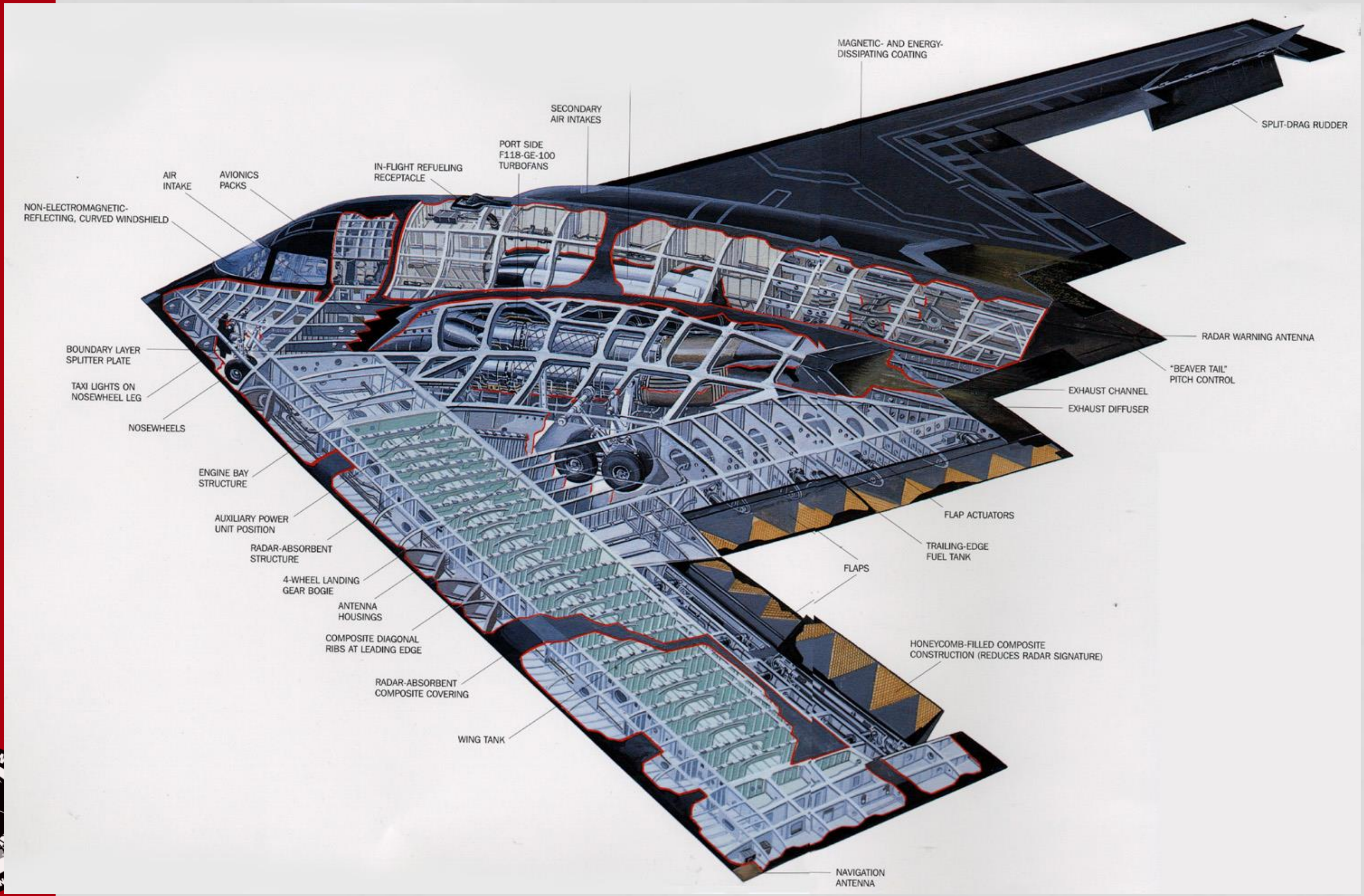
- Stealth
  - Shaping
  - RAM
- Counter Stealth
  - Bi-static radar
  - Low frequency radar (HF or VHF)
  - UWB

Stealth Techniques

- Cover in radar absorbing materials
- Use RF transparent composite materials
- Shape the target to reduce:
  - Edges
  - Surface discontinuities
  - Corners
- Shape the target to reflect energy away from the radar



Stealth Techniques



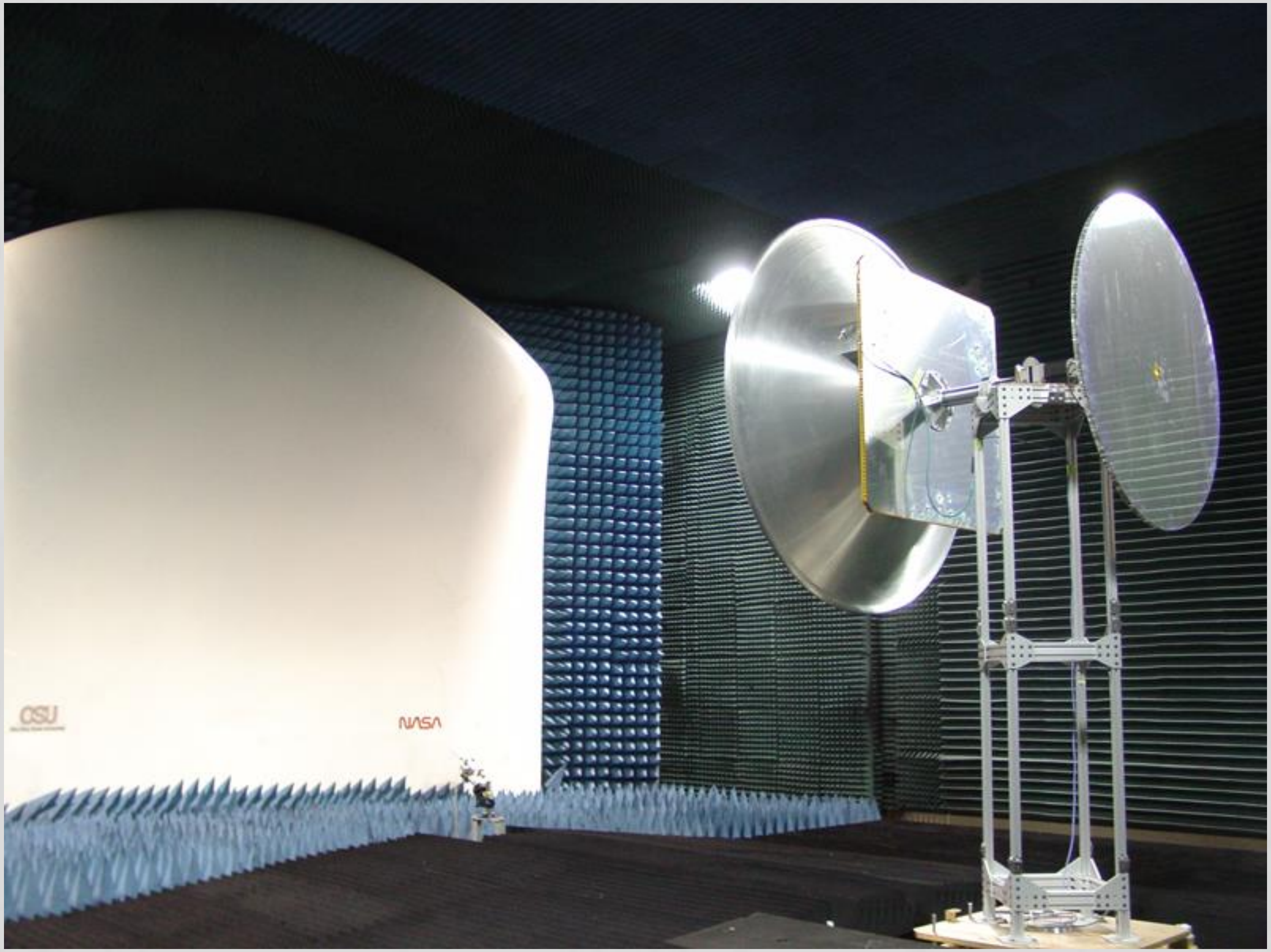
In the Navy…

Radar Absorbing Material

- Matter designed to present a specific impedance to an incident wave
- Frensel equation for the reflection coefficients at the boundary between free space and a semi-infinite medium are:

$$\Gamma_{||} = \frac{\left(\mu_r \varepsilon_r - \sin^2\theta\right)^{1/2} - \varepsilon_r \cos\theta}{\left(\mu_r \varepsilon_r - \sin^2\theta\right)^{1/2} + \varepsilon_r \cos\theta} \qquad \Gamma_{\perp} = \frac{\mu_r \cos\theta - \left(\mu_r \varepsilon_r - \sin^2\theta\right)^{1/2}}{\mu_r \cos\theta + \left(\mu_r \varepsilon_r - \sin^2\theta\right)^{1/2}}$$

Radar Absorbing Material



Radar Absorbing Material

- Reduced RCS can be obtained by coating a metallic surface with a layer of dielectric material.
- The normalized input impedance is then:

$$\eta = \sqrt{\mu_r/\epsilon_r}\,\tanh\left(-jk_0 d\sqrt{\mu_r/\epsilon_r}\right)$$

- The reflection coefficient is:

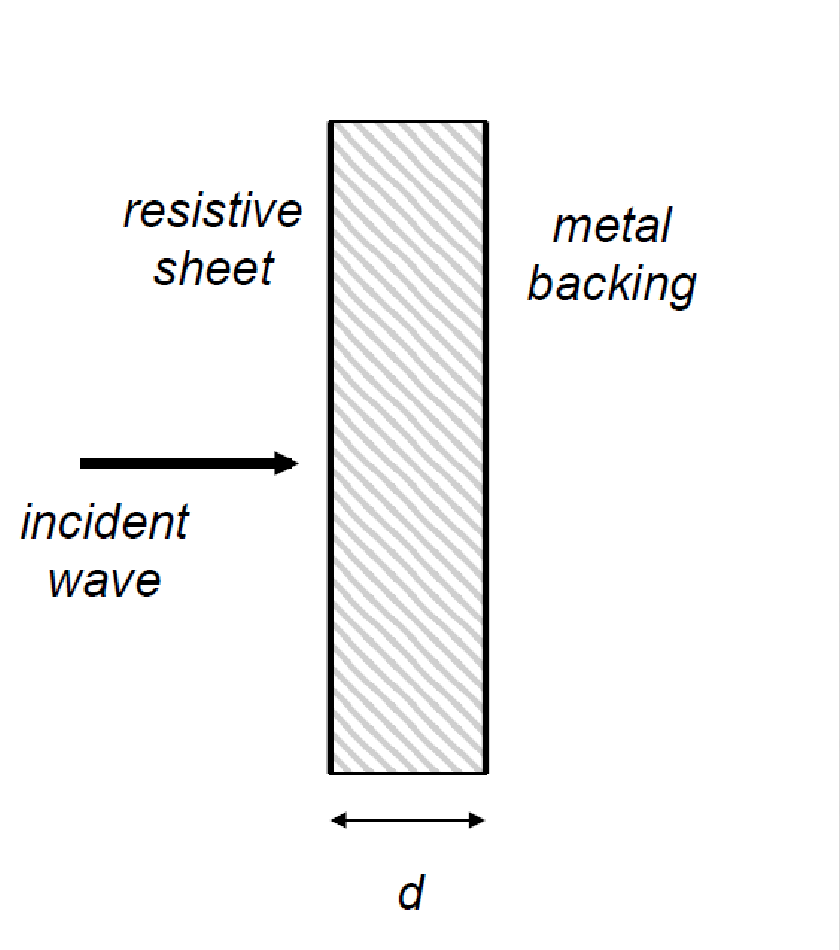
$$\Gamma = \frac{\eta - 1}{\eta + 1}$$

- This can then be expressed as a dB reduction in target RCS

$$20\log_{10}(\Gamma)$$

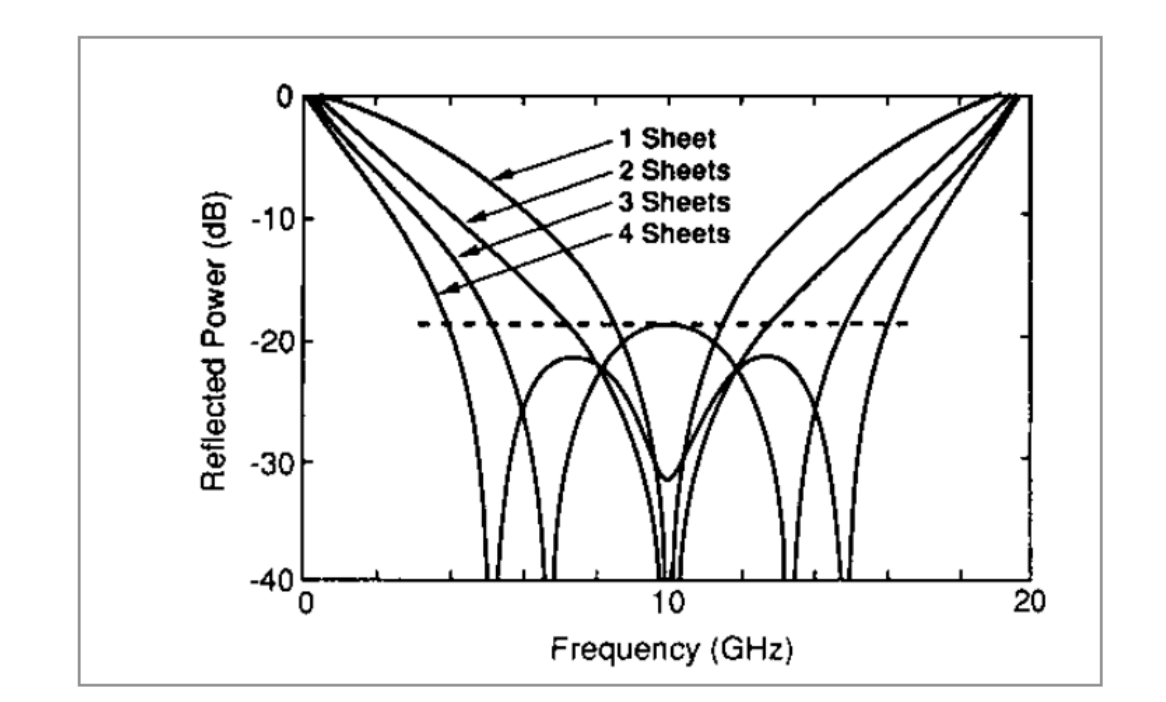
Salisbury Screen

- Consists of a resistive sheet spaced in front of a metal sheet by a low dielectric constant spacer (foam or honeycomb)
- For zero reflectivity the screen requires a resistive sheet matched to free space, spaced by odd multiples of a quarter wave



Jaumann Abosrber

- Salisbury screen can be improved by adding additional sheets and spacers.
- For the best performance the resistivity of the sheets should decrease from front to back
- More sheets, implies more bandwidth



Sensor Signatures

Antenna Mode RCS

- Assume an incident power density p, in W/m², the power reaching the antenna feed point is then

$$p\frac{G\lambda^2}{4\pi}$$

- The power reflected from the feed point is

$$|\Gamma|^2\frac{pG\lambda^2}{4\pi}$$

- Where Γ is the voltage reflection coefficient. This is reradiated, creating an antenna mode RCS in the direction of the antenna beam of:

$$\sigma_A = \frac{G^2\lambda^2|\Gamma|^2}{4\pi}$$

- **While the reflection coefficient my be low within the operating band of the radar, outside that band it may approach unity, creating a very high antenna mode RCS**

Structural Mode RCS

- Defined as the RCS obtained when the antenna is terminated in a matched load (literature definitions are inconsistent)

Some Example RCS

Small, single engine aircraft	1 m^2
Jumbo jet	100
Small open boat	0.02
Frigate (1000 tons)	5,000
Truck	200
Car	100
Bicycle	2
Person	1
Bird	0.01
Insect	10^{-5}

RCS Measurement

the HP 8510.

* HP-IB is Hewlett-Packard's hardware, software, documentation, and support for IEEE-488 and IEC-625, worldwide standards for interfacing instruments.

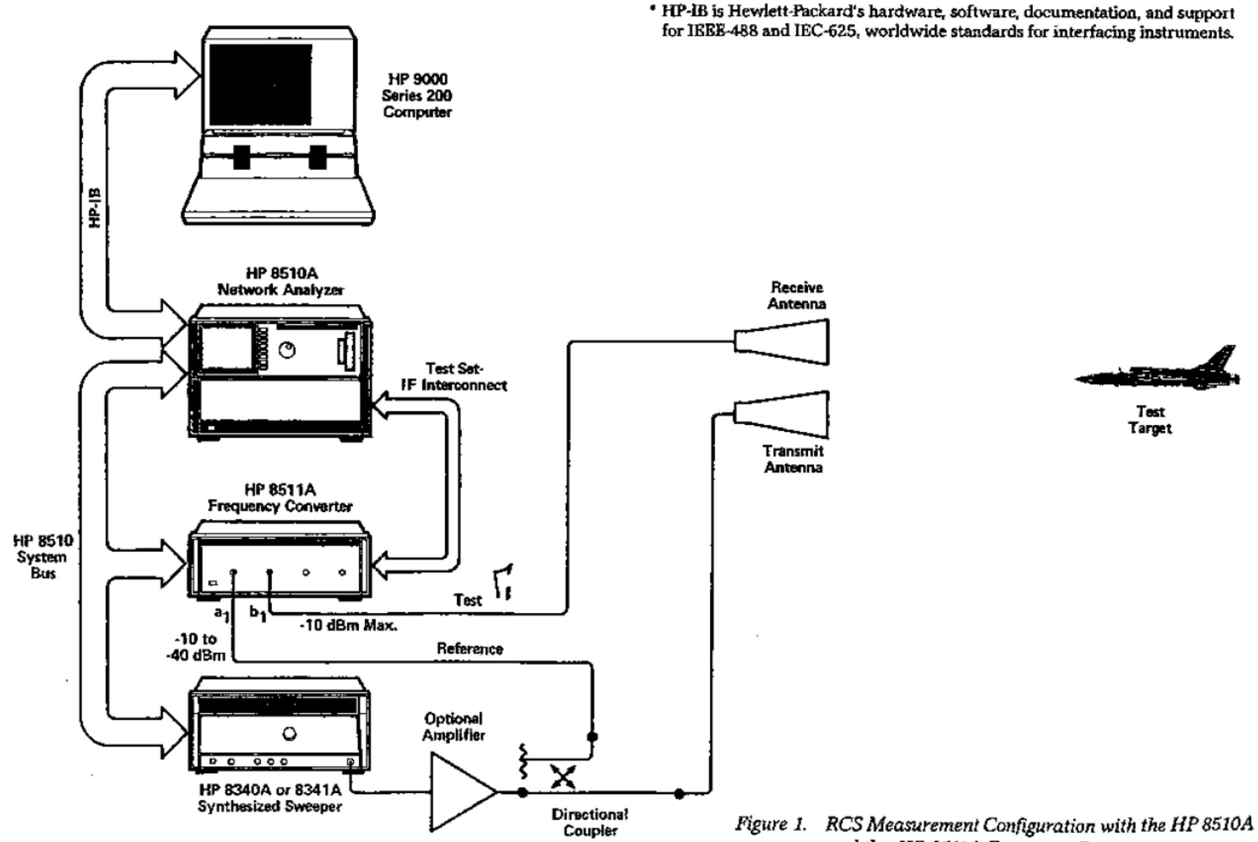


Figure 1. RCS Measurement Configuration with the HP 8510A and the HP 8511A Frequency Converter.

Stealth and Detection Range

- Examining the radar range equation reducing the target RCS from 100 m2 to 0.01 m2 reduces the detection range by a factor of 10

$$r_{\max} = \left[\frac{P_t G^2 \lambda^2 \sigma L}{(4\pi)^3 k T_0 B F \, S/N_{\min}} \right]^{1/4}$$

Countering Stealth

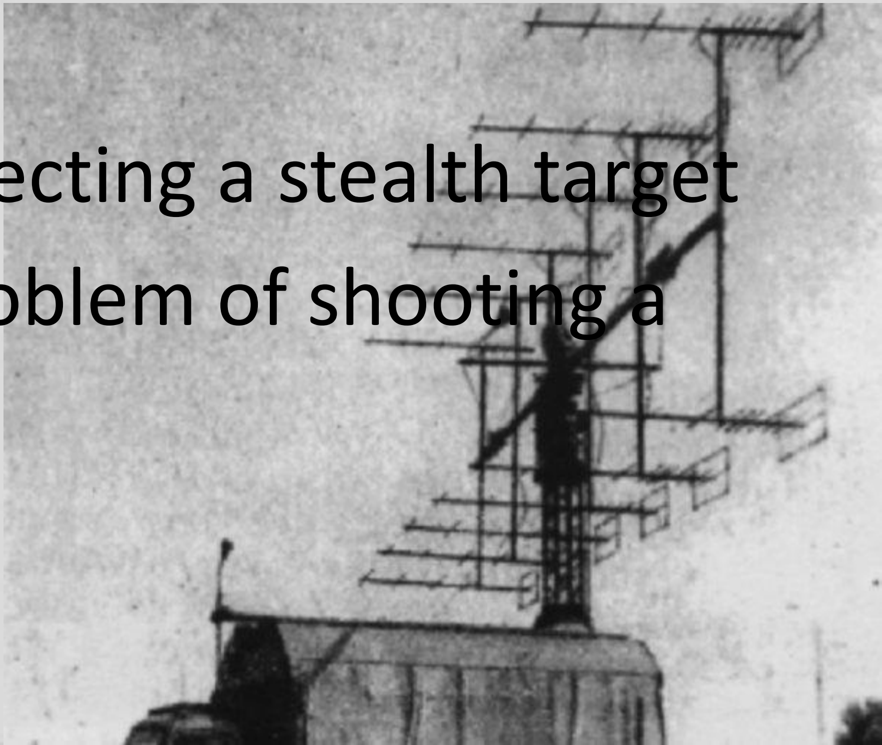
- There are several radar techniques that may be used to attempt to restore the advantage that comes from making a target stealthy :
  - Bistatic radar, since energy scattered in directions other than the monostatic direction may be intercepted by a bistatic receiver
  - Low frequency (VHF or HF) radar, since the target signature is increased at frequencies at which the target dimensions are resonant, and RAM is less effective at low frequencies
  - Ultra wideband (UWB) radar, which may exploit any target resonances, and because it is difficult to make a target stealthy over a very broad bandwidth
  - Networked radars
  - There are also several techniques that can be used to win performance in conventional radars, such as improved clutter models, reduced phase noise, improved tracking algorithms, and several ways of exploiting the flexibility of phased array radars.

Bistatic Radar

- RCS reduction techniques aimed principally at minimising monostatic RCS; bistatic geometry can intercept energy scattered in other directions
- Forward scatter geometry can give high RCS, even with truly stealthy targets;
- Passive receiver, immune to interception;
- Can utilise ‘illuminators of opportunity’

Low Frequency Radar

- VHF-ish…
- Requires a very large array
- Range and angular resolution may be limited
- Best solution for detecting a stealth target
- Doesn’t solve the problem of shooting a missile at it



Example Radar – Spoon Rest

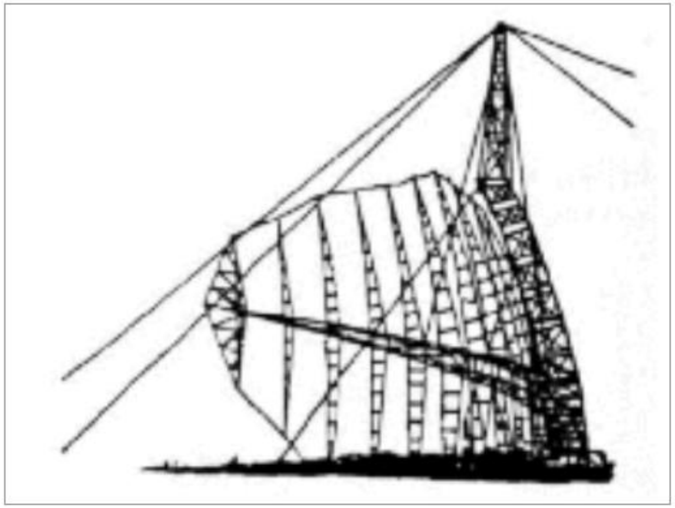
- The Spoon Rest A-band warning and target acquisition radar has a range of 275 km using a large Yagi antenna array. At regimental HQ for the V-75 SA-2 GUIDELINE there is a fourth Spoon Rest, a van-mounted P-15 Flat Face 250 km range C-band search and tracking radar with two elliptical parabolic reflectors and a PRV-11 Side Net 180 km range E-band nodding height-finder radar mounted on a box-bodied trailer. There is also a radar control truck and a Mercury Grass truck-mounted command communications system for linking the HQ to the three battalions.

Spoon Rest

Function:	Target acquisition, early warning
Range	275 km
Frequency	A versions: A band (VHF) B versions: VHF below A band
Power	314 kW, BW 6x22.5
PRF	310-400pps
PW	4-6 μs
Max Alt	32 km
Scan	2-6 rpm
Associated weapon system	SA-2 GUIDELINE FAN SONG fire control radar
Recognition	Six yagi array with bisecting crossbar mast mounted on 6x6 truck; in transit, two truck carry array and generator

TALL KING

Function	Early Warning
Range	605 km
Frequency	A Band
Scan	2-6 rpm



TALL KING