Lecture 1:

- Radar: Radio Detection and Ranging
- Block schematic diagram
- Radar bands
- Radar range equation

The transmitter "fires" a signal and the receiver waits until it detects the echo.

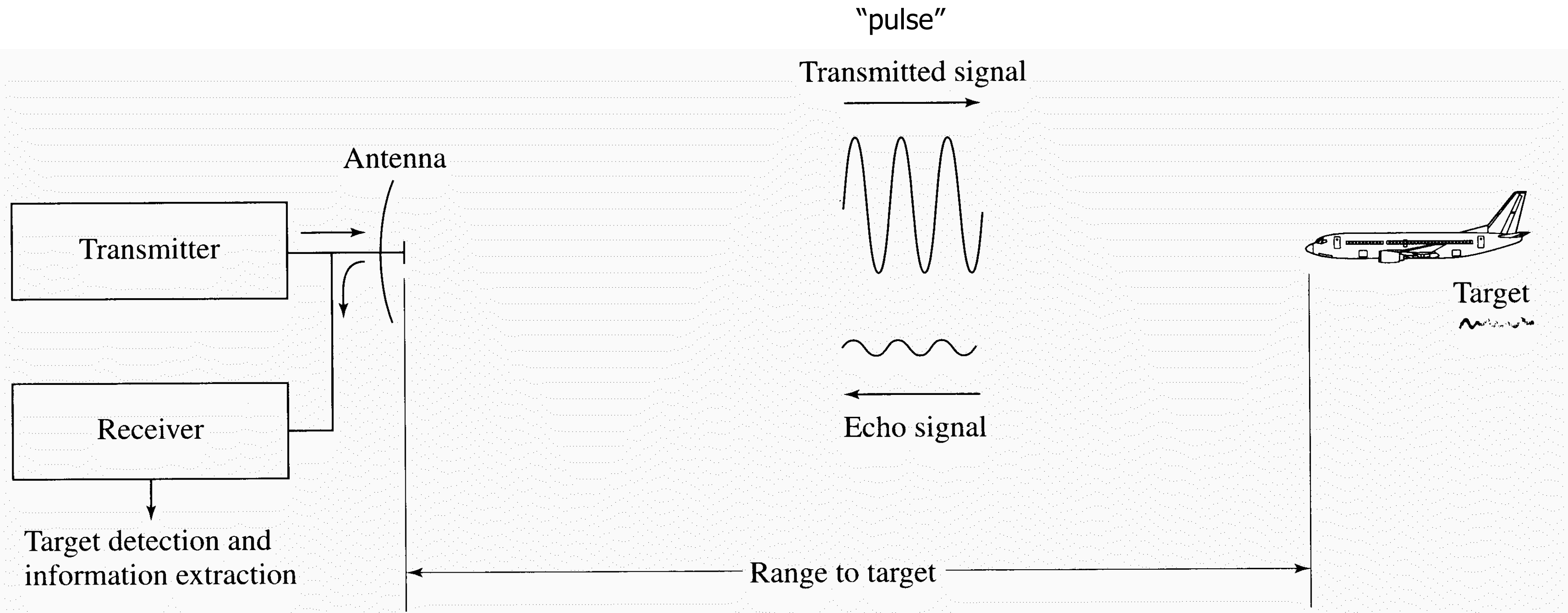


Figure 1.1 Basic principle of radar.

The waiting time between the epoch of transmit and the epoch of receive gives the range.

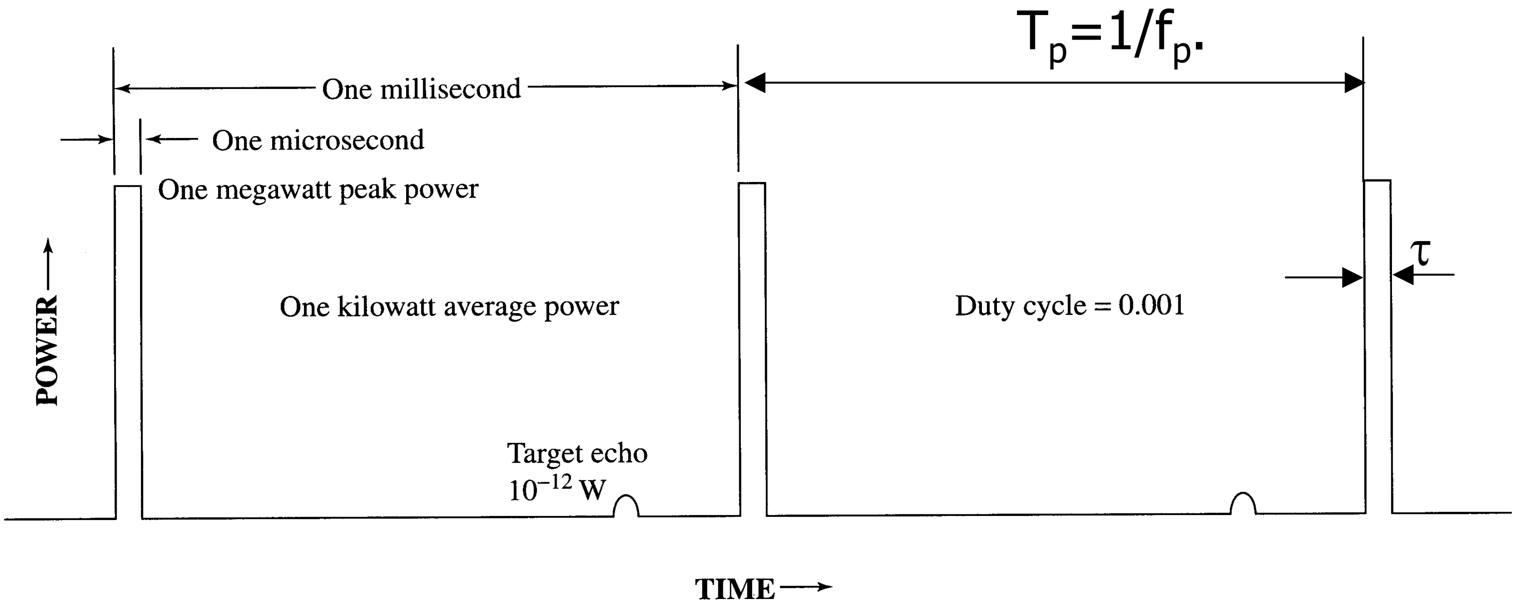


Figure 1.3 Example of a pulse waveform, with "typical" values for a medium-range air-surveillance radar. The rectangular pulses represent pulse-modulated sinewaves.

(note the orders of magnitude!!)

$$R_{\max,unamb} = \frac{c}{2}\cdot\frac{1}{f_p} = \frac{c}{2}\cdot\frac{1}{PRF} = \frac{c}{2}\cdot PRT = \frac{c}{2}\cdot PRI$$

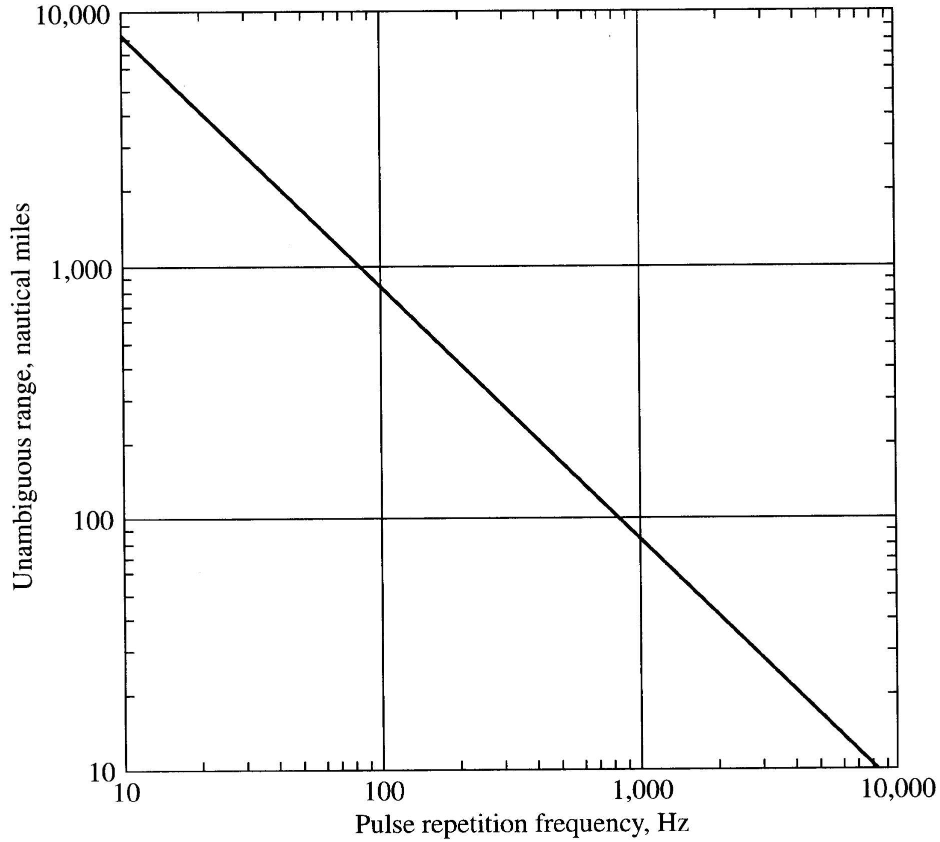
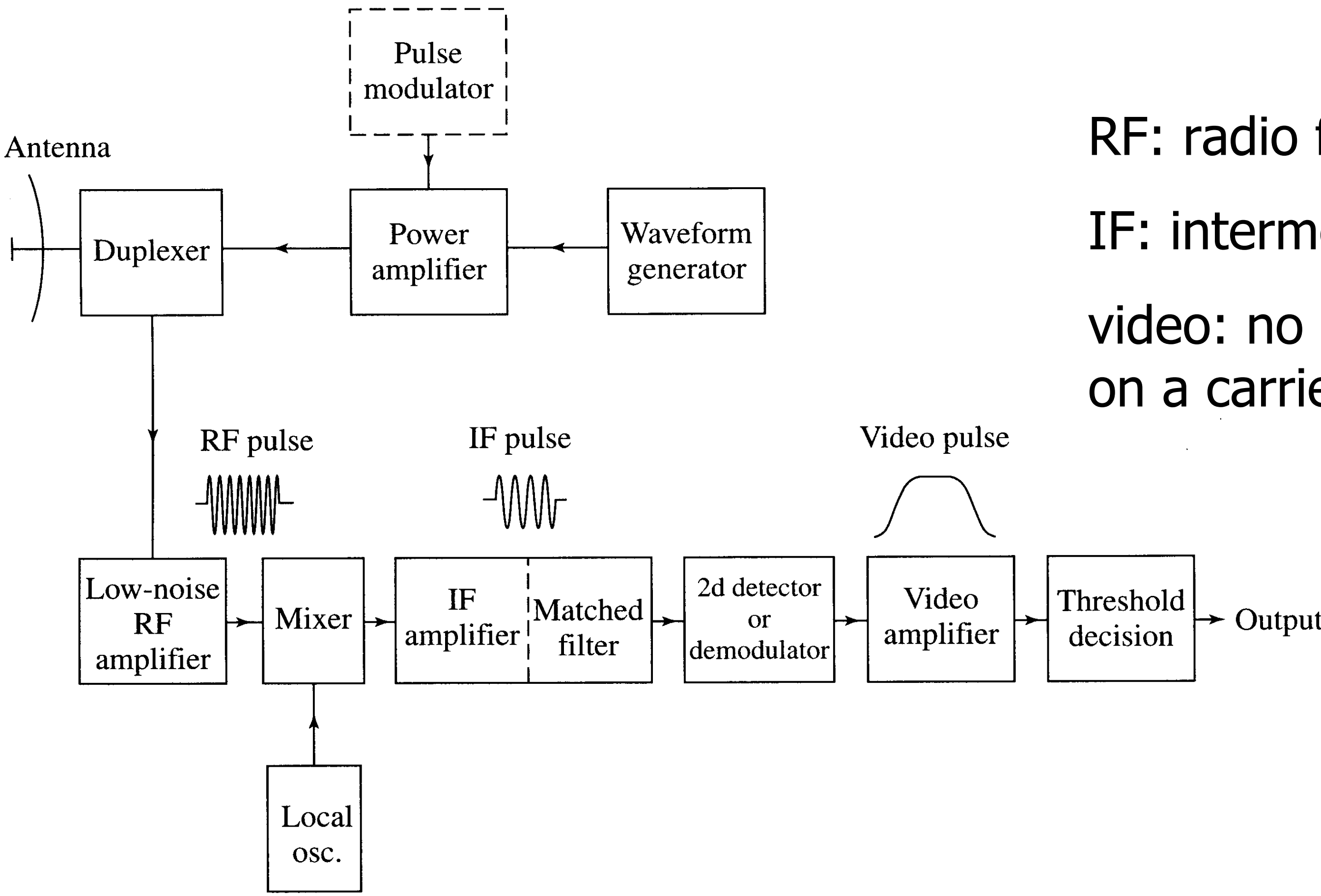


Figure 1.2 Plot of Eq. (1.2), the maximum unambiguous range R_{un} as a function of the pulse repetition frequency f_p.

Basic block diagram of a pulse radar



RF: radio frequency

IF: intermediate frequency

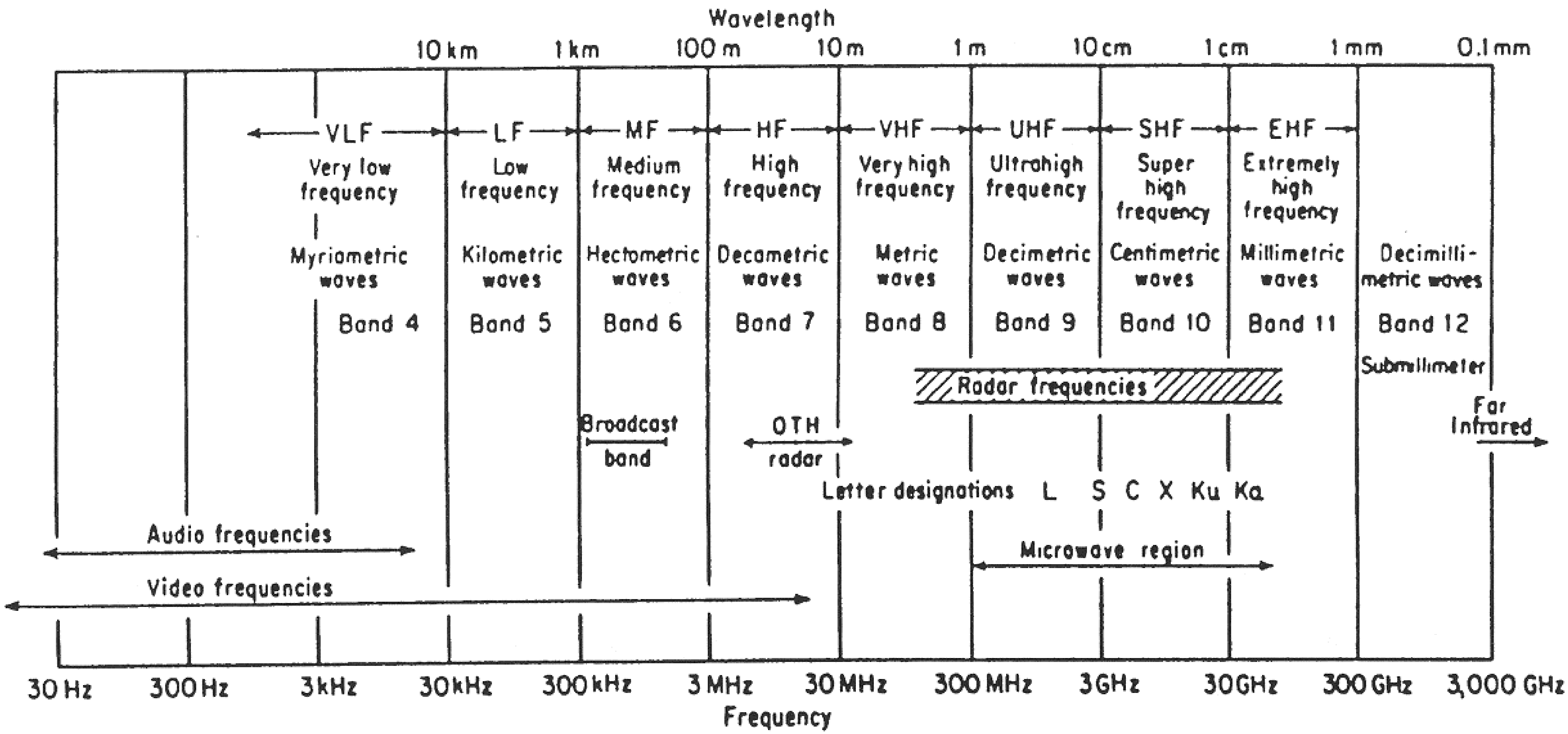
video: no more modulated on a carrier (base band)

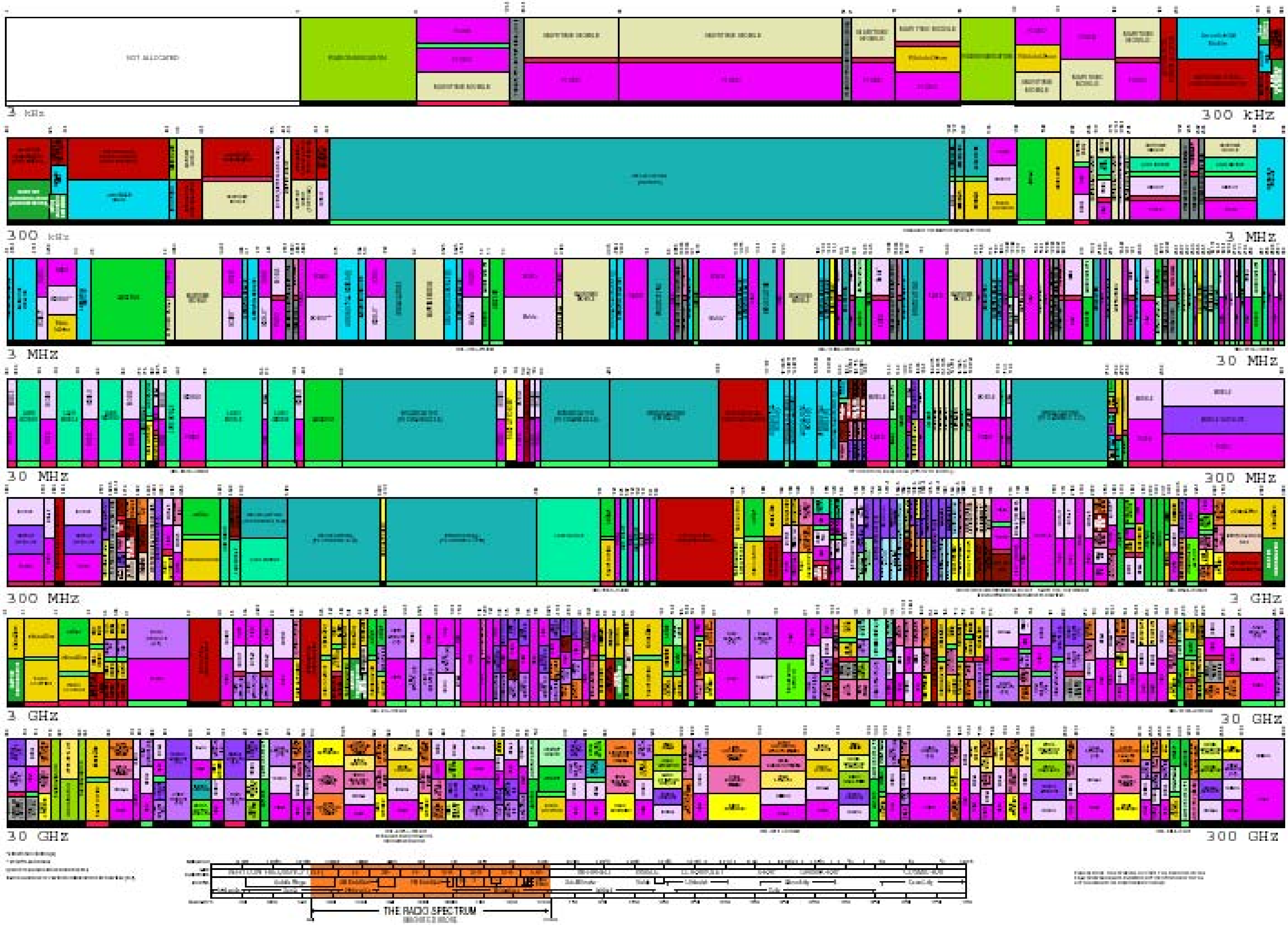
Table 1.1 IEEE standard radar-frequency letter-band nomenclature*

Band Designation	Nominal Frequency Range	Specific Frequency Ranges for Radar based on ITU Assignments in Region 2
HF	3–30 MHz	
VHF	30–300 MHz	138–144 MHz 216–225 MHz
UHF	300–1000 MHz	420–450 MHz 850–942 MHz
L	1–2 GHz	1215–1400 MHz
S	2–4 GHz	2300–2500 MHz 2700–3700 MHz
C	4–8 GHz	5250–5925 MHz
X	8–12 GHz	8500–10,680 MHz
K_u	12–18 GHz	13.4–14.0 GHz 15.7–17.7 GHz
K	18–27 GHz	24.05–24.25 GHz
K_a	27–40 GHz	33.4–36 GHz
V	40–75 GHz	59–64 GHz
W	75–110 GHz	76–81 GHz 92–100 GHz
mm	110–300 GHz	126–142 GHz 144–149 GHz 231–235 GHz 238–248 GHz

*From "IEEE Standard Letter Designations for Radar-Frequency Bands," IEEE Std 521–1984.

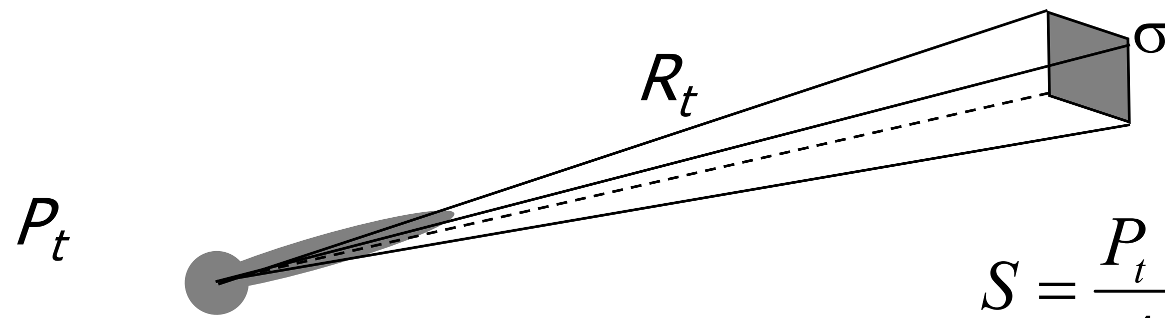
NATO designations are different from IEEE's standard!




3 kHz
300 kHz
300 kHz
3 MHz
3 MHz
30 MHz
30 MHz
300 MHz
300 MHz
3 GHz
3 GHz
30 GHz
30 GHz
300 GHz
THE RADIO SPECTRUM

$$P_r = \frac{G_t G_r P_t W_\sigma \lambda^2}{(4\pi)^3 R^4}$$

Radar Range equation



$$S = \frac{P_t \cdot \sigma \cdot G_t}{4\pi \cdot R^2}$$

$$S = \frac{P_t \cdot \sigma \cdot G_t}{4\pi \cdot R^2}$$

$$P_r = \frac{A_e . S}{4\pi R^2}$$

With $A_e = \frac{G_r \lambda^2}{4\pi}$ one arrives at $P_r = \frac{G_t G_r P_t \cdot \sigma \cdot \lambda^2}{(4\pi)^3 R^4}$

$$P_r = \frac{G_t G_r P_t \cdot \sigma \cdot \lambda^2}{(4\pi)^3 R^4} \quad R_{\max} = \left(\frac{P_t G_t G_r W_\sigma \lambda^2}{(4\pi)^3 P_{r,\min}} \right)^{1/4}$$

Or by isolating R:

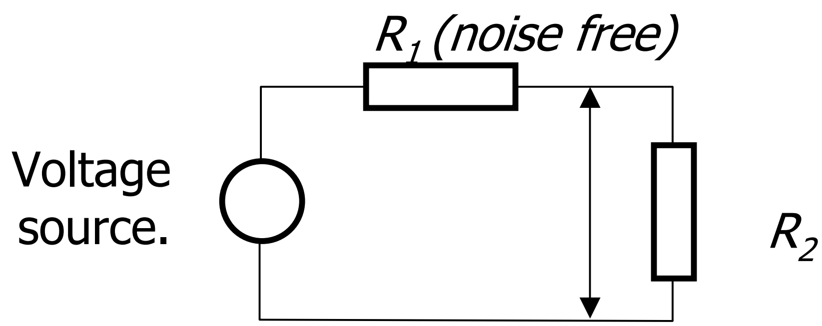
$$R_{\max} = \left(\frac{P_t G_t G_r \sigma \cdot \lambda^2}{(4\pi)^3 P_{r,\min}} \right)^{1/4}$$

Indicating $P_{r,min}=S_{min}$ the equation yields:

$$R_{\max} = \left(\frac{P_t G_t G_r \sigma \lambda^2}{(4\pi)^3 S_{\min}} \right)^{1/4}$$

The open terminal voltage of a noisy resistor is sqrt(4kTB) Volts.

The power that can be dissipated by this resistor can be computed according to the following substitution model:



Then the maximum power that can be dissipated in the load R_2 is, when $R_1=R_2$.

In this case this maximum power is:

$$\frac{4kTR_1B}{4R_1} = kTB$$

Introducing the noise figure F as:

$$F = \frac{noise\ out\ of\ a\ practical\ receiver}{noise\ out\ of\ an\ ideal\ receiver\ at\ temperature\ T_0}$$

$$F = \frac{N_o}{N_{ideal}}$$

$$F = \frac{N_o}{kT_0 B G_a}$$

After $G_a = S_o / S_i$ one finds:

$$F = \frac{S_i N_o}{kT_0 B S_o} \quad \text{and} \quad S_{i,\min} = \left(\frac{S}{N}\right)_{o,\min} kT_0 BF$$

Substituting this in the radar range equation and including loss factors on transmit and receive:

$$R_{\max} = \left(\frac{P_t G_t G_r \sigma \lambda^2}{(4\pi)^3 k T_0 B F \left(\frac{S}{N}\right)_{o,\min} L_t L_r} \right)^{1/4}$$

TU Delft

Example: Radar range equation

$$R_{\max} = \left(\frac{P_t G_t G_r \sigma \quad \lambda^2}{(4\pi)^3 \, k \quad T_0 \quad B \quad F \left(\frac{S}{N} \right)_{o,\min} \quad L_t L_r} \right)^{1/4}$$

			numerator	denominator
Peak power	10log(P)	P=50 kW	47	
Antenna Gain	20log(G)	G=33 dB	66	
RCS	10log(RCS)	RCS=1 m^2	0	
Wavelength	20 log(λ)	λ=0.1 m	-20	
$(4\pi)^3 kT_0$				-171
Bandwidth 10 log(B)	B=1 MHz			60
Noise figure		3 dB		3
Required S/N	Pd=80%; Pfa=10^{-6}			17.9
Transmit and receive losses		1+2 dB		3
Subtotals			93	-87.1

40 log Rmax = 180.1 dB $\rightarrow$ **Rmax=31805 m.**