3.2 *Electromagnetic noise*

1. Noise
2. Transmitter spectra and masks
3. Representation vs frequency and direction
4. Suppression approaches

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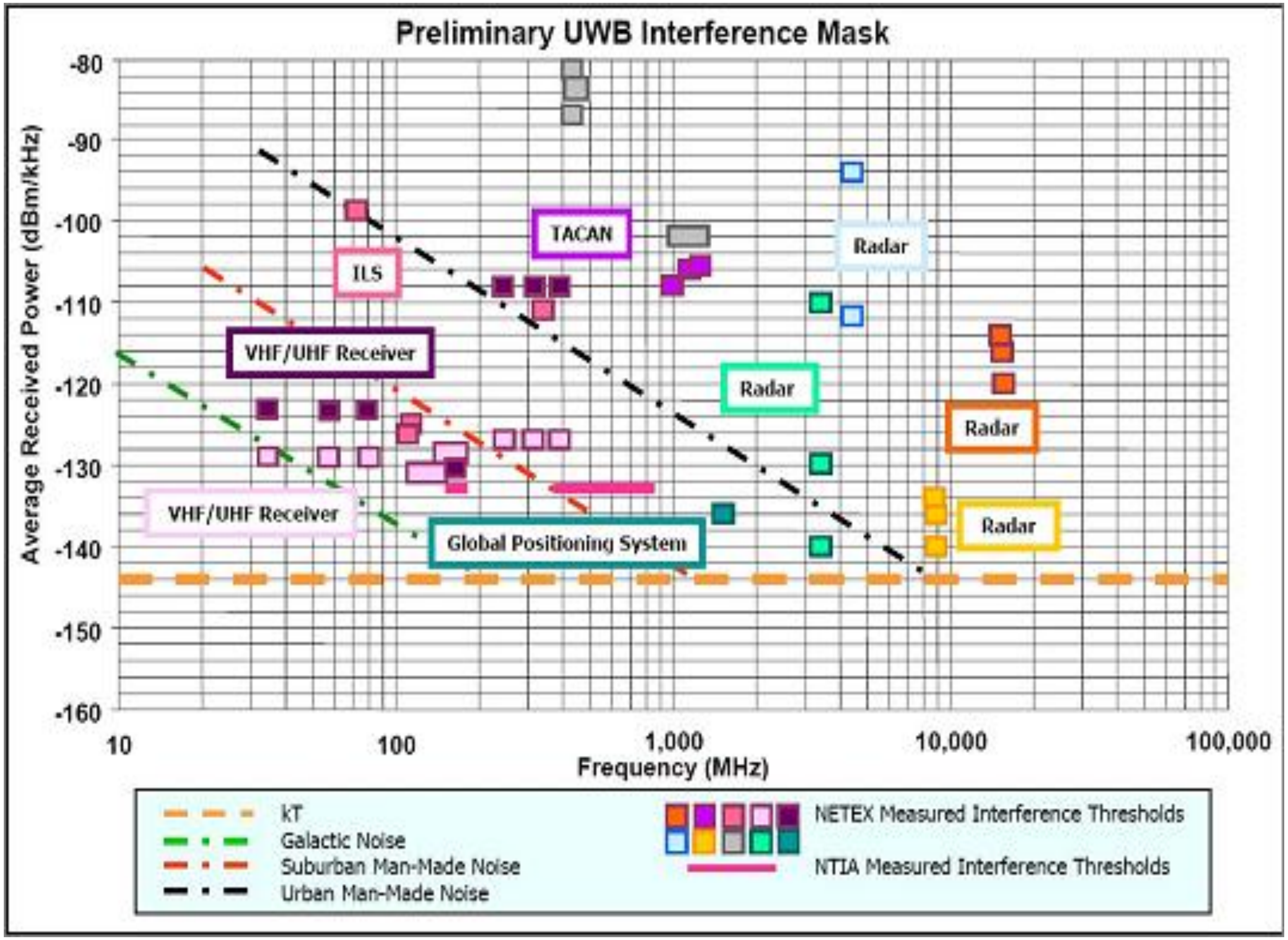
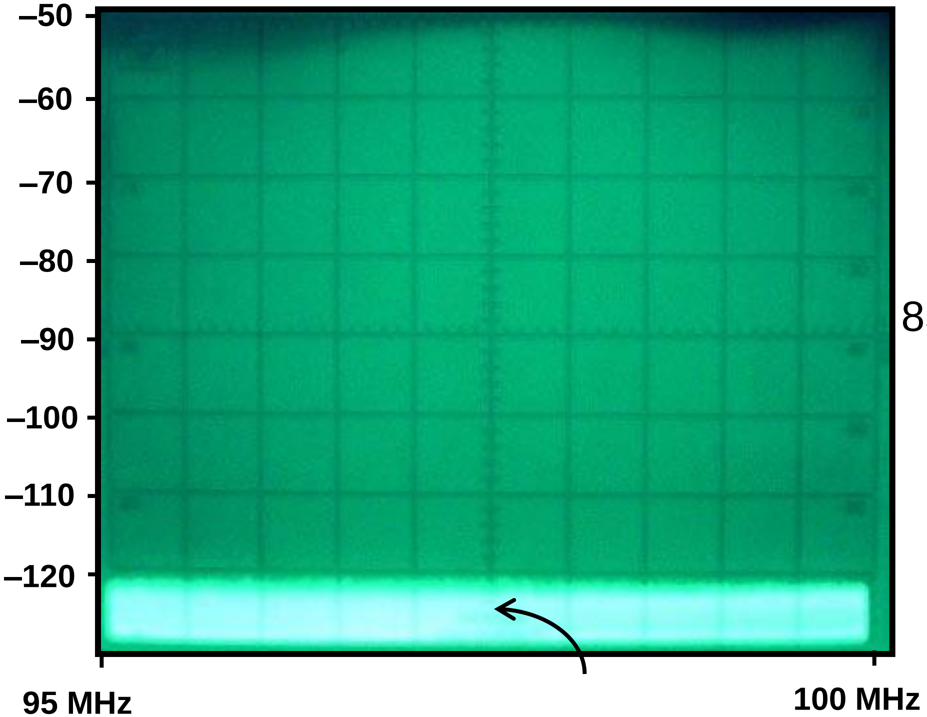
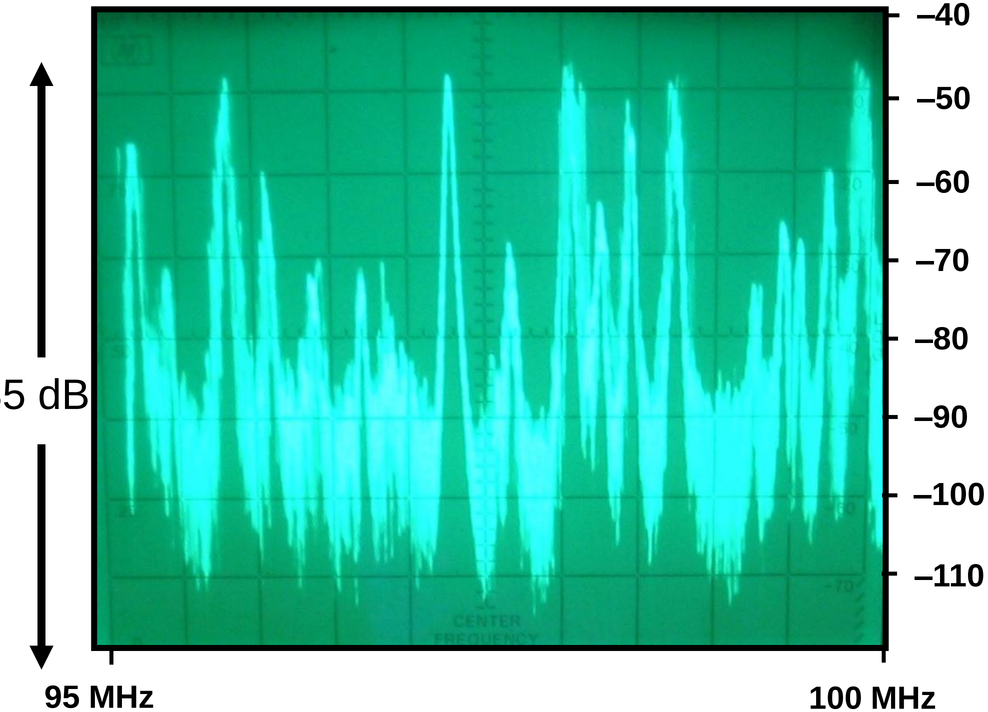
Noise and interference



Noise level

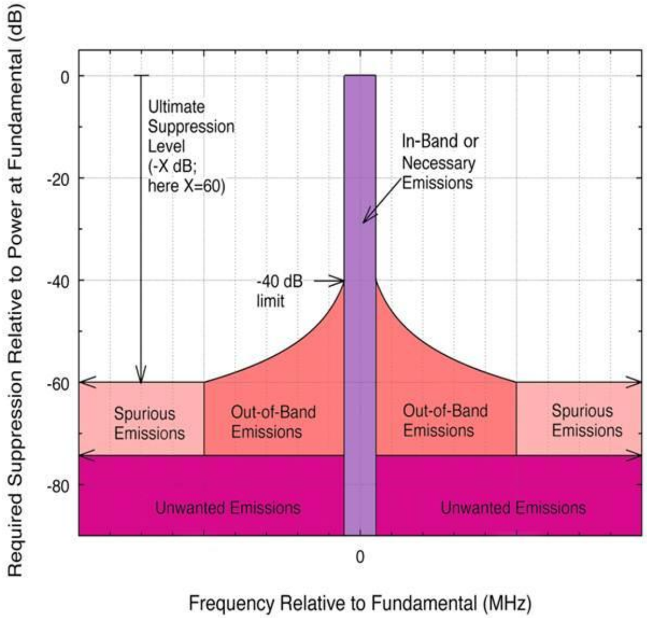


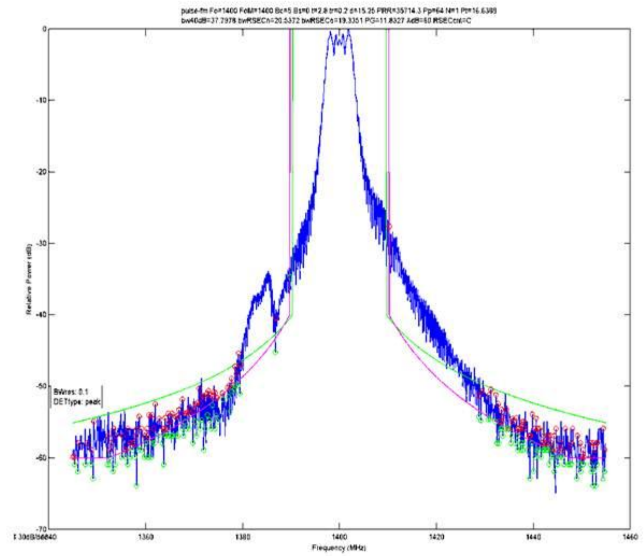


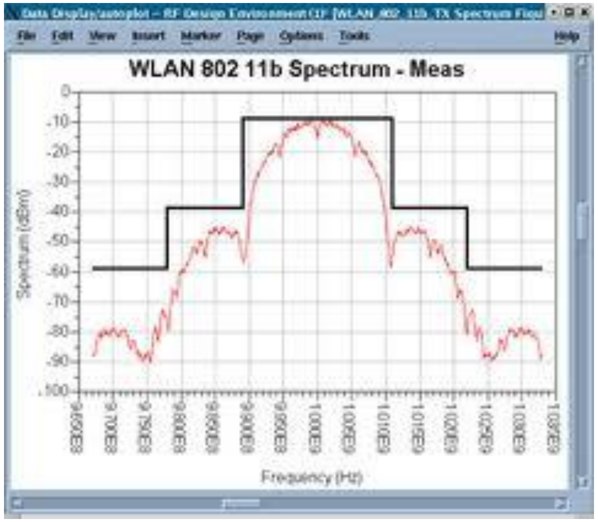
$P_n = kT_0BF$ = –122 dBm in B = 50 kHz

Noise levels in a passive radar receiver in FM radio band: (i) thermal noise in 50 kHz bandwidth corresponding to 5 dB receiver noise figure; top of screen = –50 dBm (ii) signal and noise levels measured from 10th floor of UCL in Central London on vertically-polarised dipole antenna; top of screen = –40 dBm.

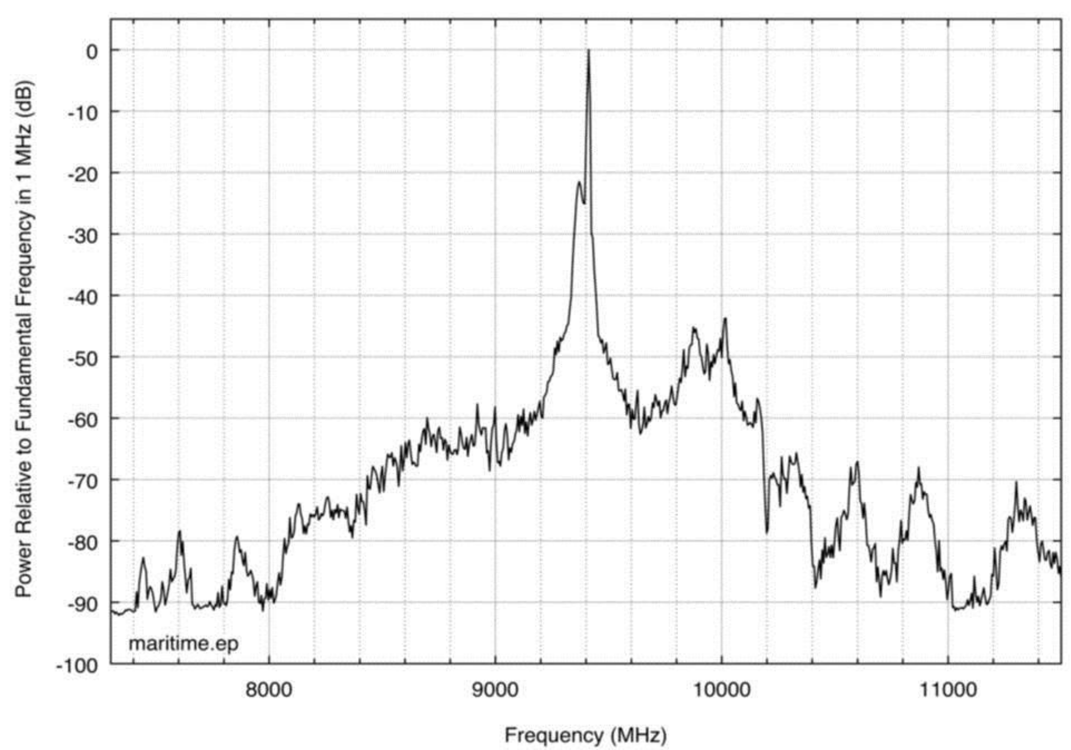
Spectral masks





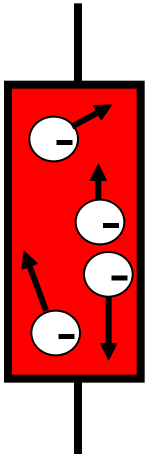


Magnetron spectrum



Thermal Noise (White)

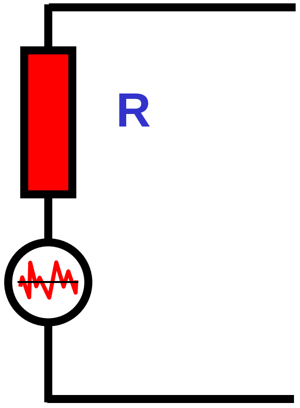
• **Thermal noise can be well approximated by a Gaussian distribution in time**



<u>It has been shown that the Mean Square Thermal Noise Voltage is</u>

$$\sigma^2 = 4kTRB \qquad [V^2]$$

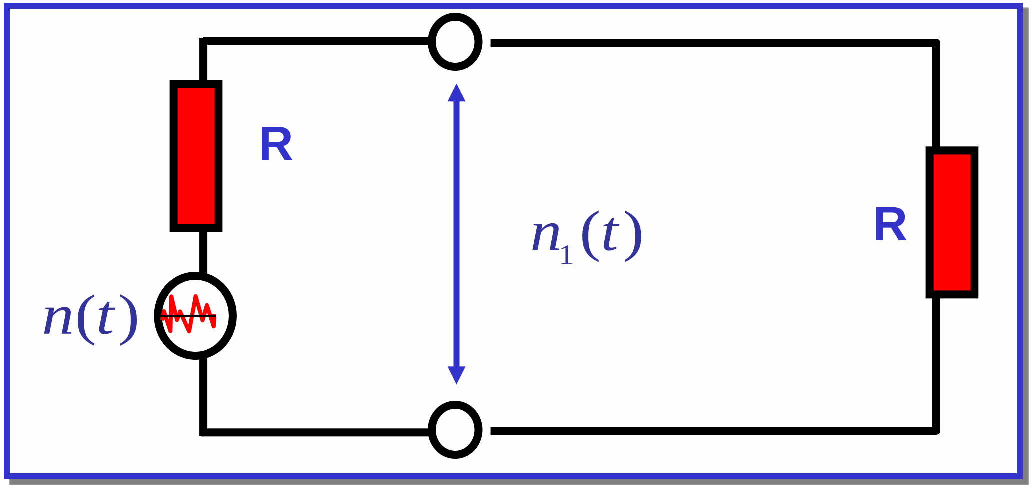
<u>Equivalent Noise Sources</u>



Voltage $n(t)$

k is Boltzmann's constant , equal to 1.38 x 10^{-23} J/deg

Matched Noise Power



$$n_1(t) = n(t)\frac{R}{R+R} = \frac{n(t)}{2}$$

$$E\{n_1(t)^2\} = \frac{E\{n(t)^2\}}{4}$$

$$E\{n_1(t)^2\} = \frac{4kTRB}{4} = kTRB$$

<u>Noise Power, N, generated in a matched load</u>

$$P = \frac{E\{V^2\}}{R} = \frac{E\{n_1^{\ 2}\}}{R} = KTB \qquad \text{Watts}$$

<u>Noise Power,N_0 generated in a matched load, per unit bandwidth</u>

- N_0 = kT W/Hz Noise Power Spectral Density
- At standard temp, T_0, of 290^0 this gives 4×10^{-21} W/Hz
- Measured per MHz at T_0, this becomes 4×10^{-15} W/MHz

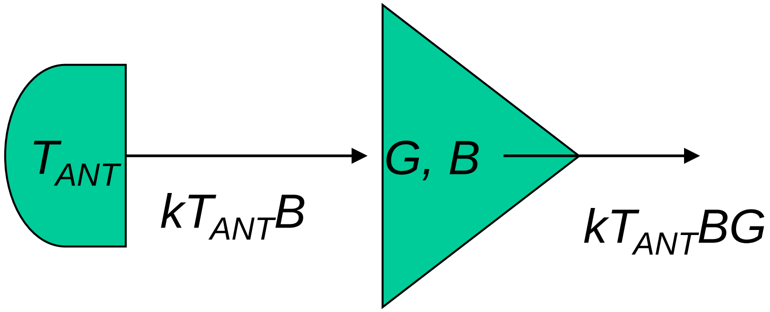
Antenna Noise Temperature

Assume a measurement of the power of the electronic magnetic noise at the antenna output is P_{EM}

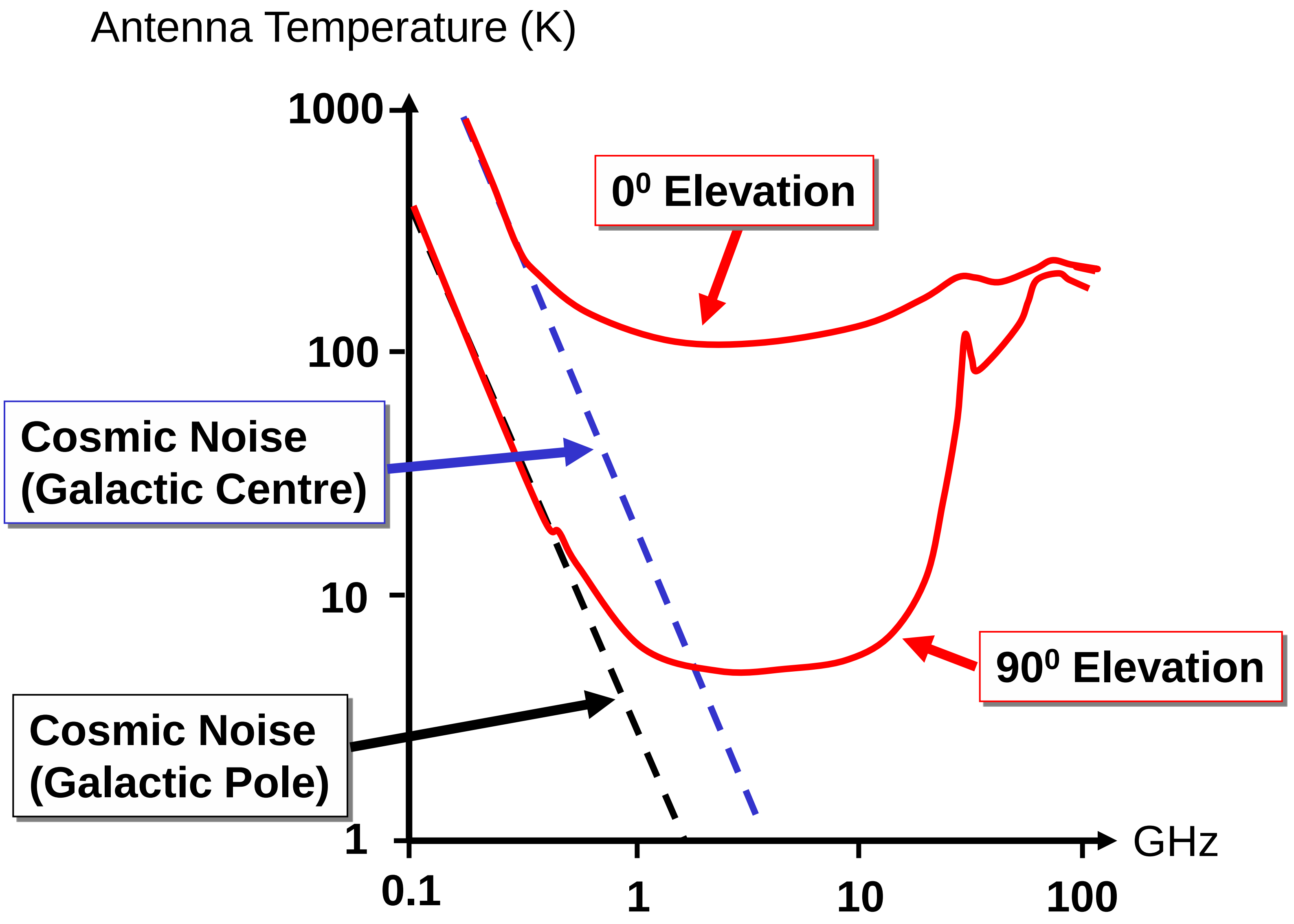
We define the antenna equivalent noise temperature T_{ANT} as the temperature (measured in degree K) that would generate the output P_{EM} if the electromagnetic noise were Gaussian.

$$P_{EM} = kT_{ANT}B$$

- *B* is the bandwidth of the receiver
- *K* is the Boltzmann's constant
- T_{ANT} is measured is degree K



Typical Antenna Noise Temperature



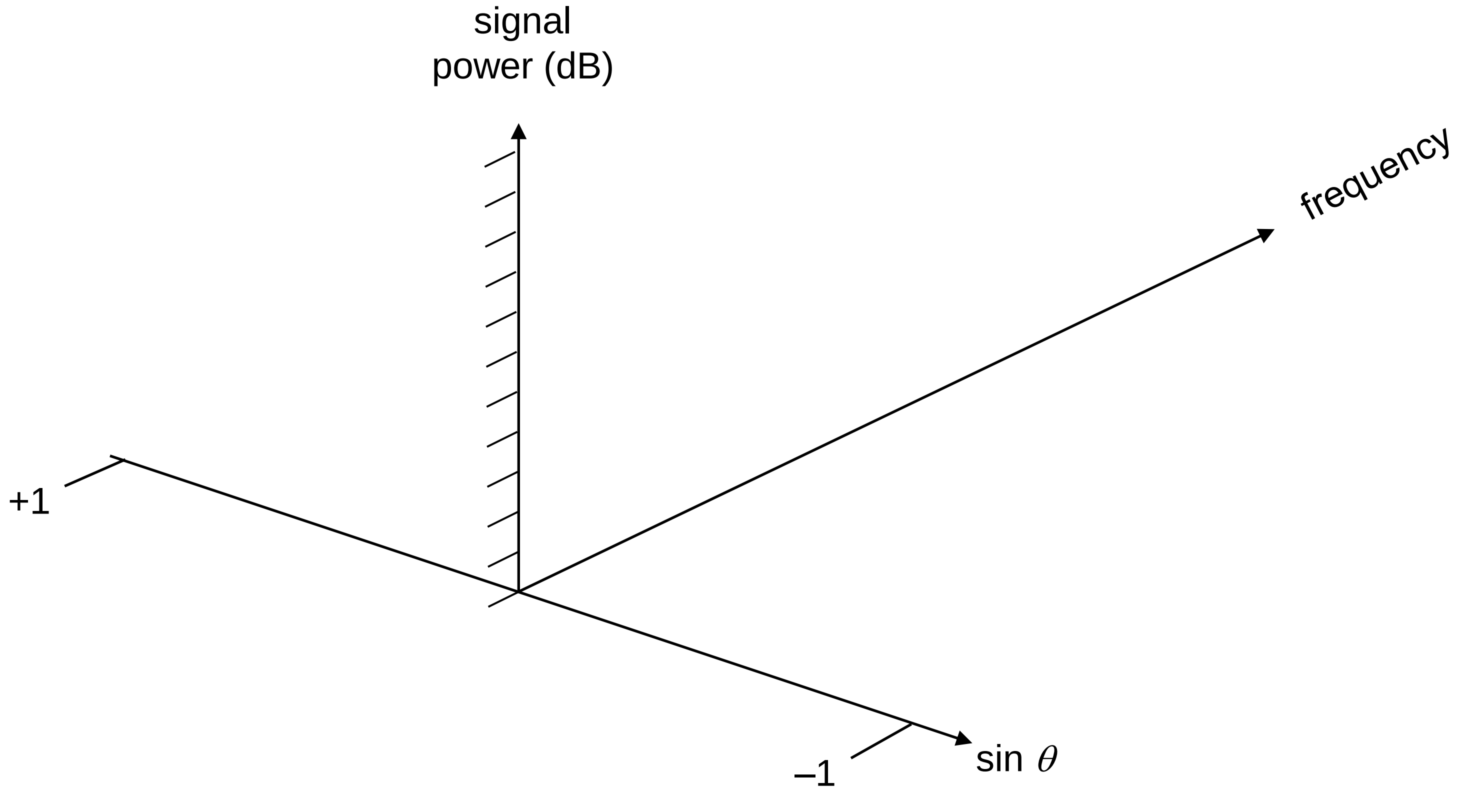
Noise and interference

We can view the noise and interference level as a two-dimensional function P(θ, f) of direction and frequency. To suppress the noise and interference we can use a combination of:

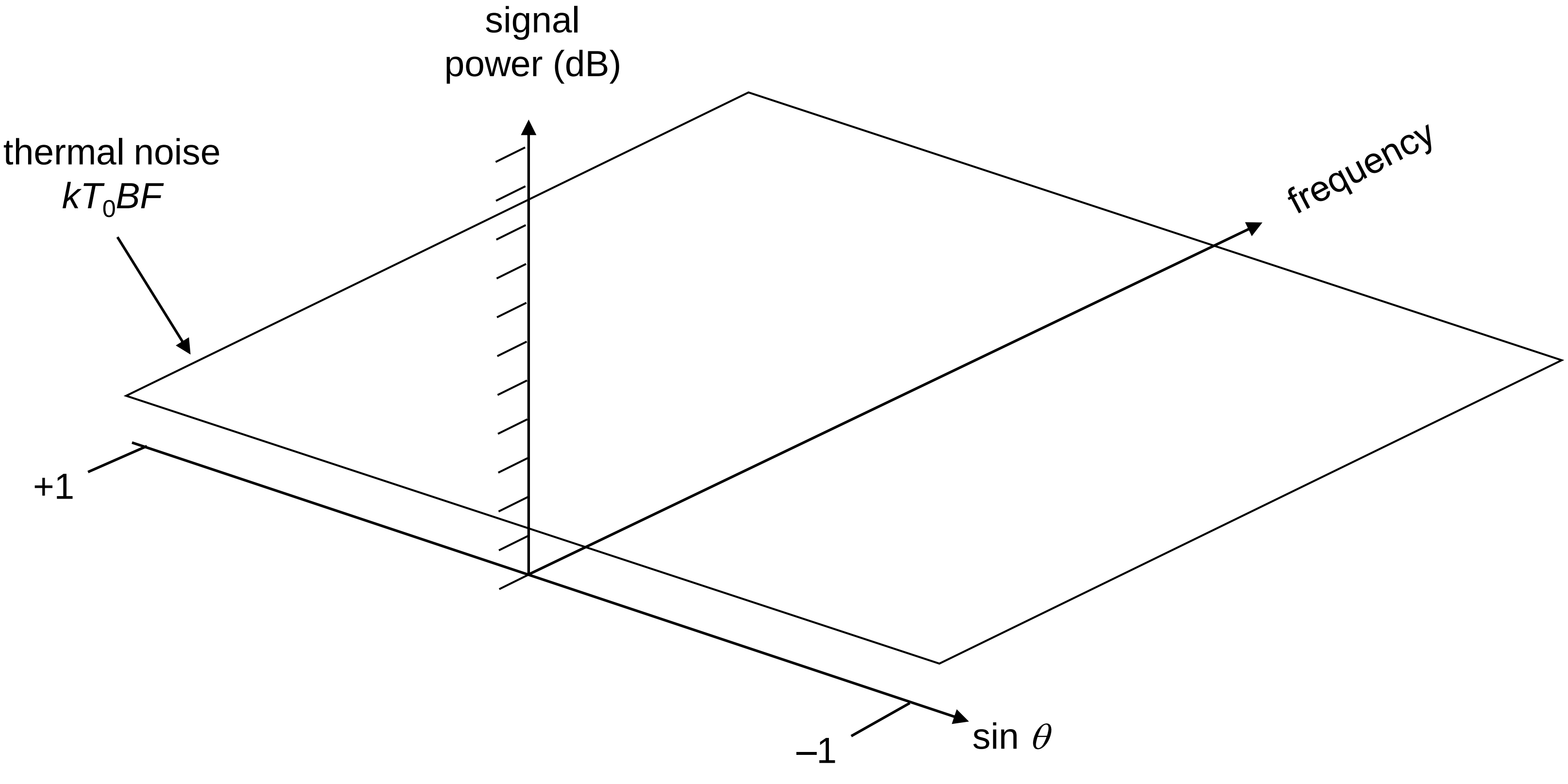
- physical shielding
- directional antennas
- null steering / adaptive beam forming
- Doppler (Fourier) processing

In order to reduce the dynamic range requirement on A-D converters it may be useful to precede the digitisation by analogue null steering.

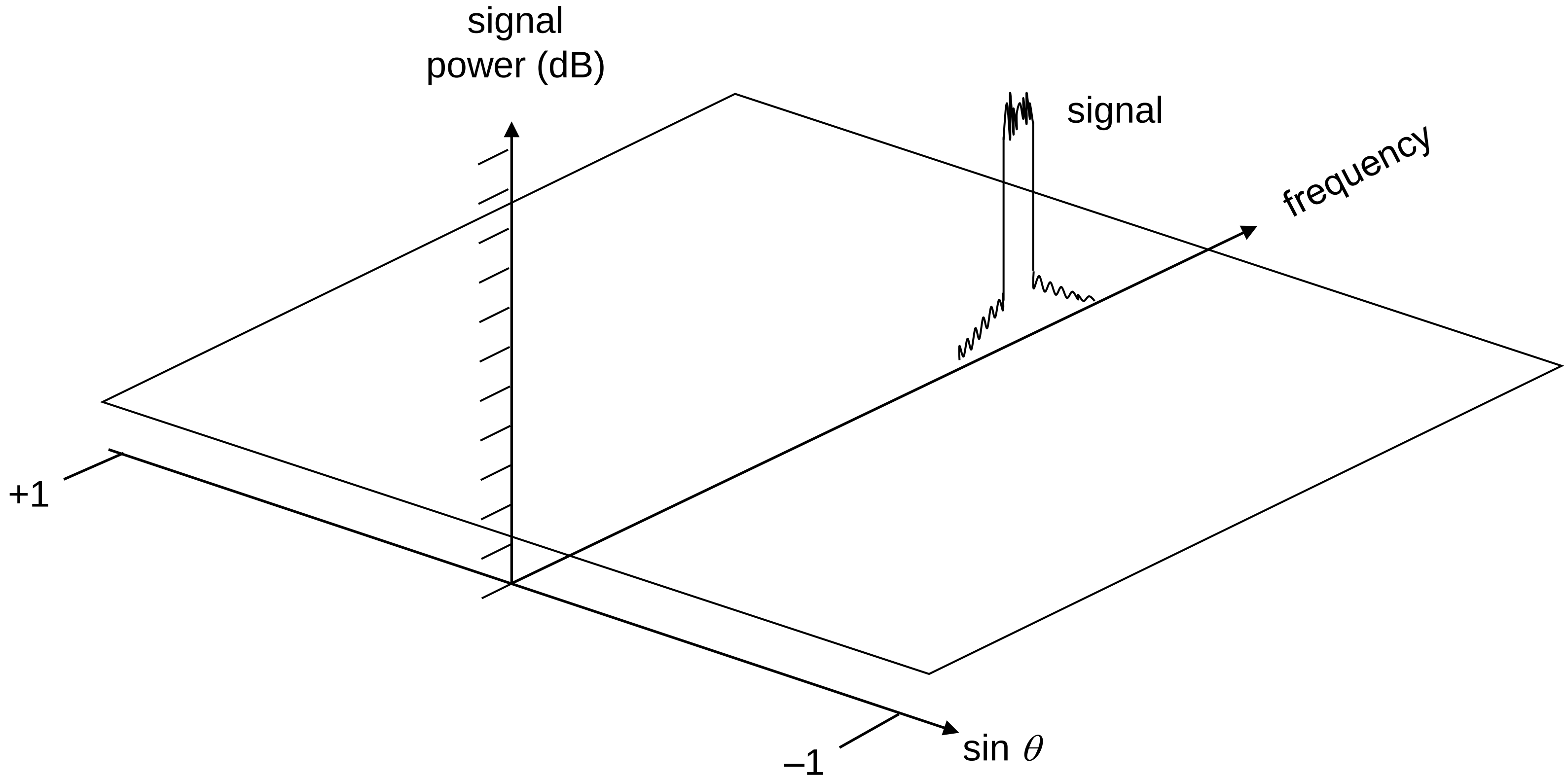
Noise and interference



Noise and interference



Noise and interference



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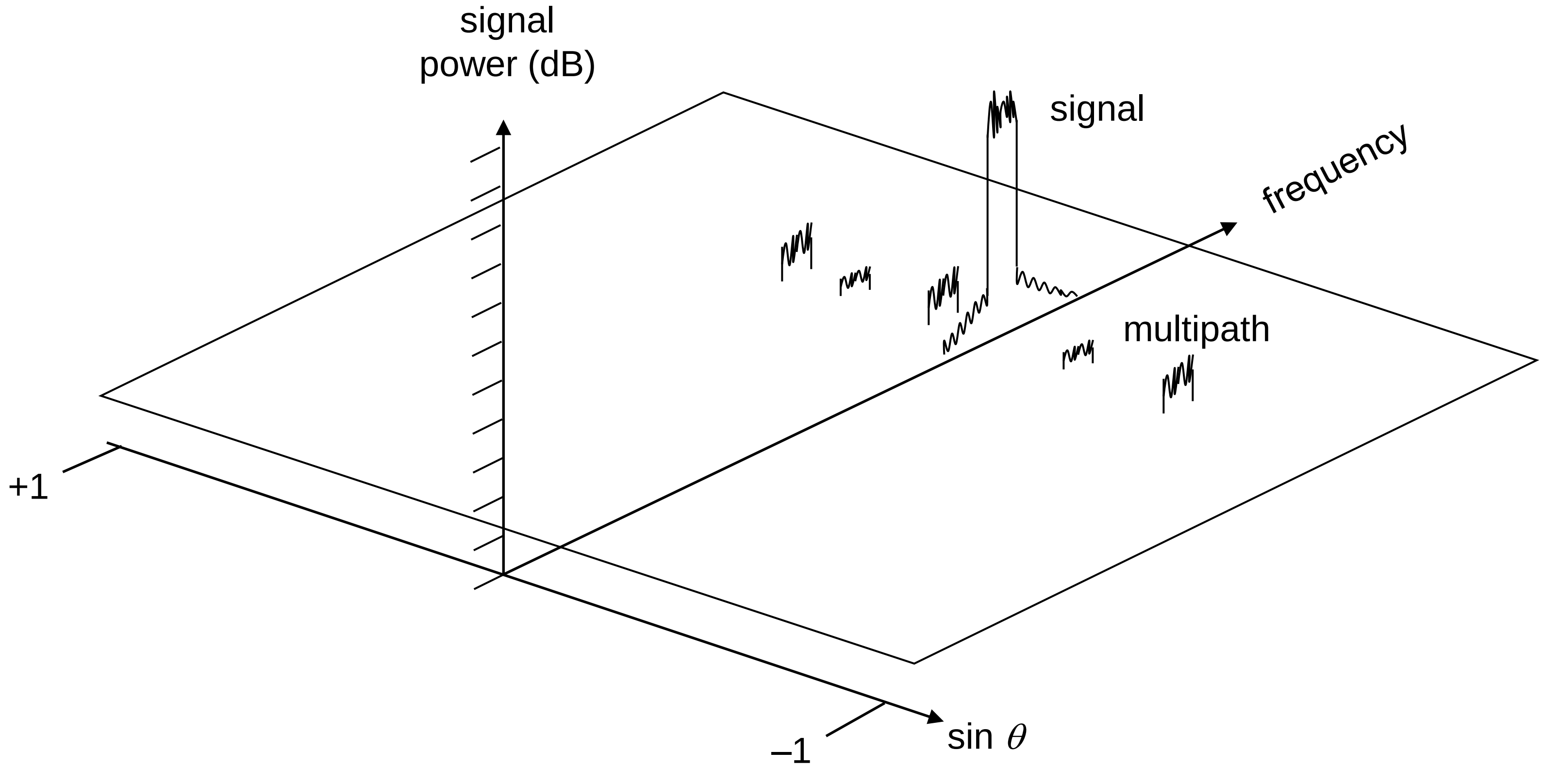
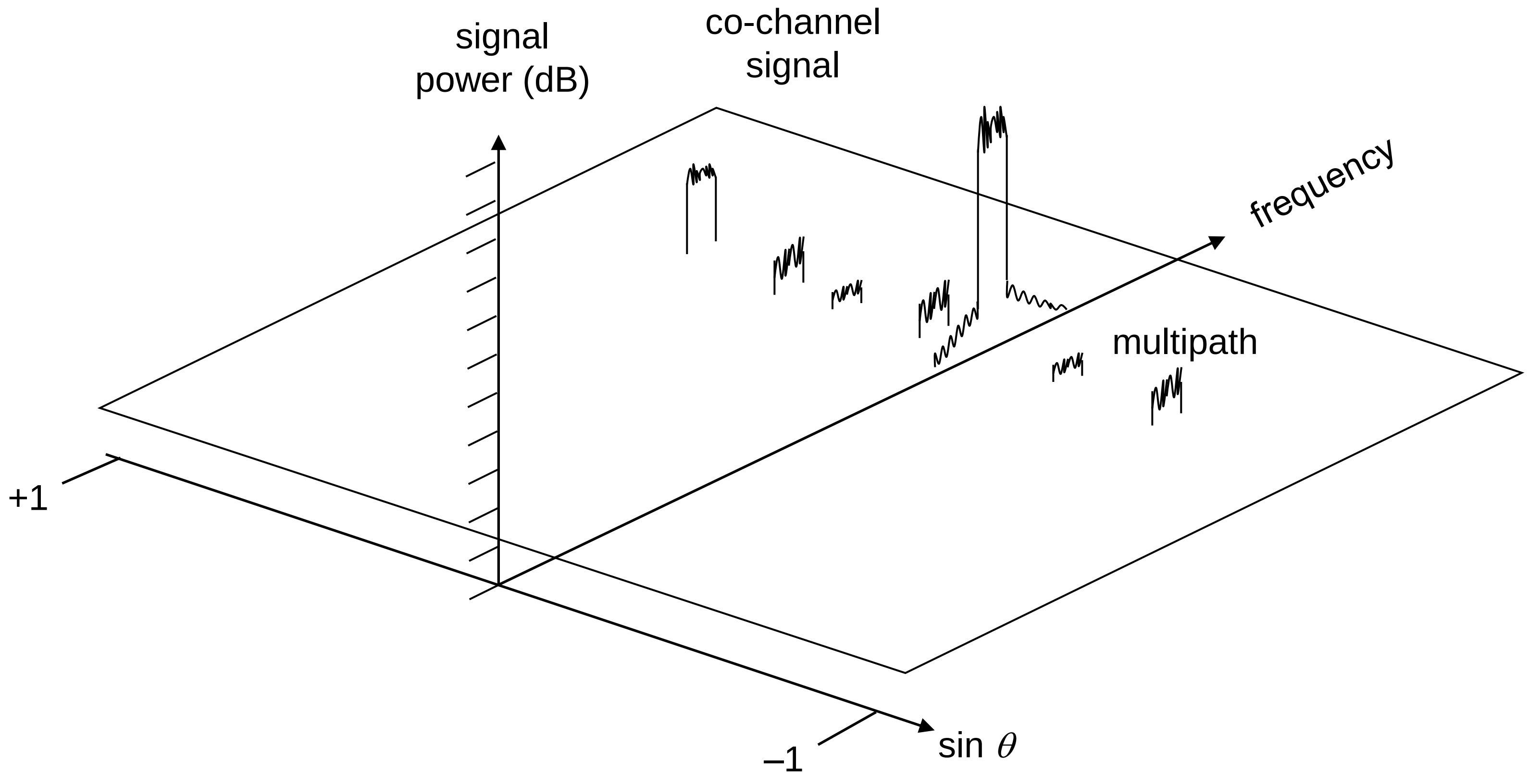
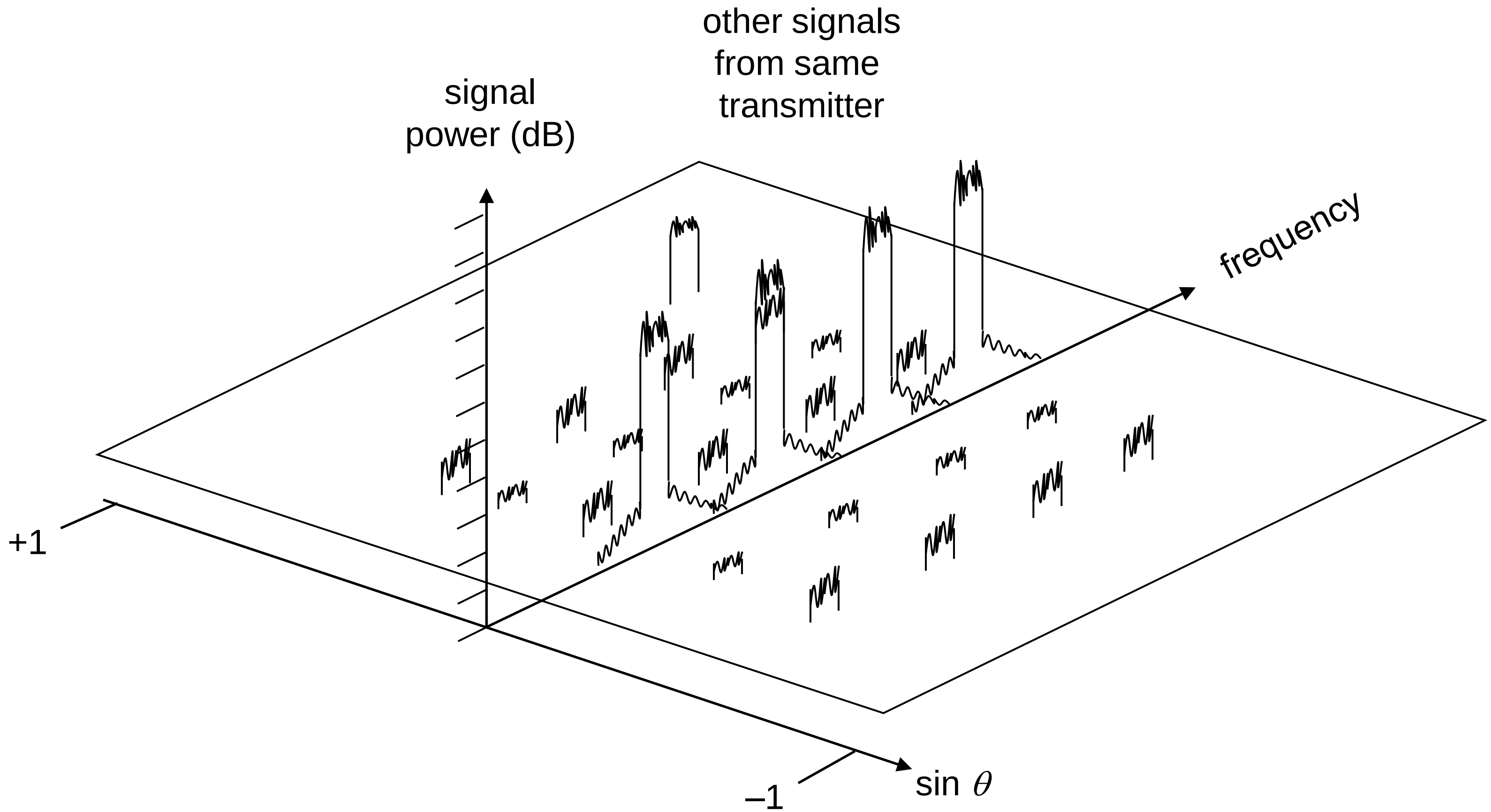


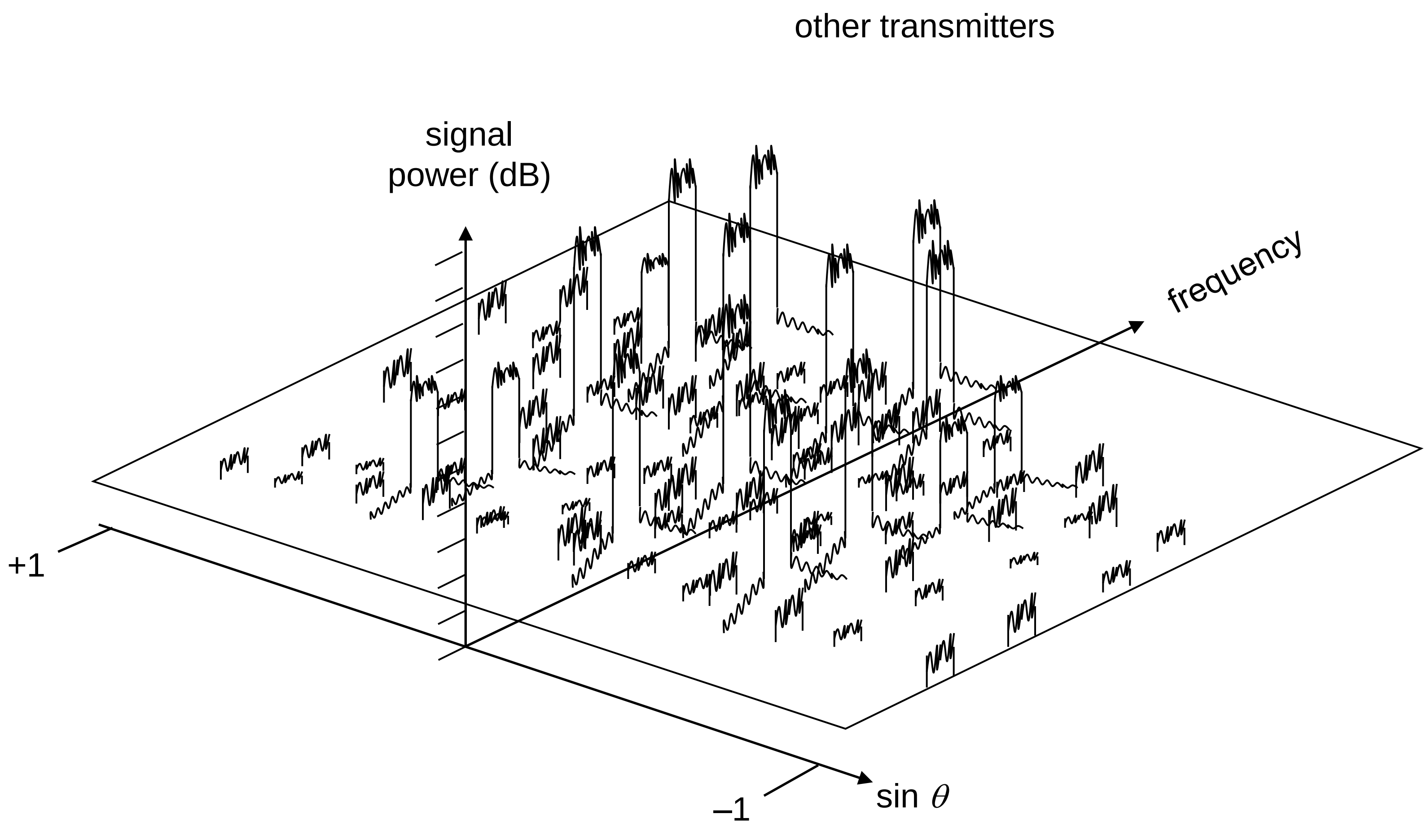
Noise and interference



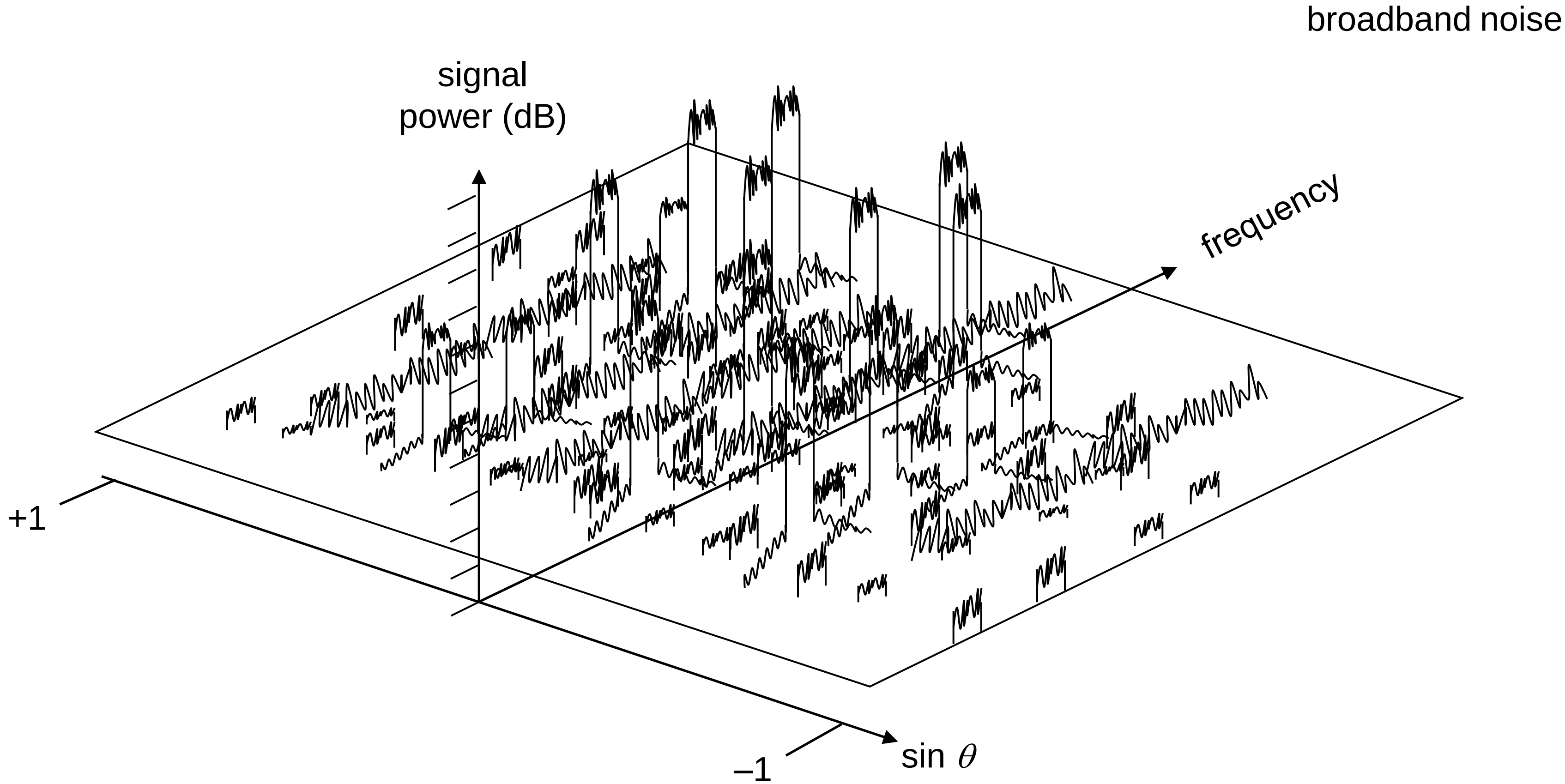
Noise and interference



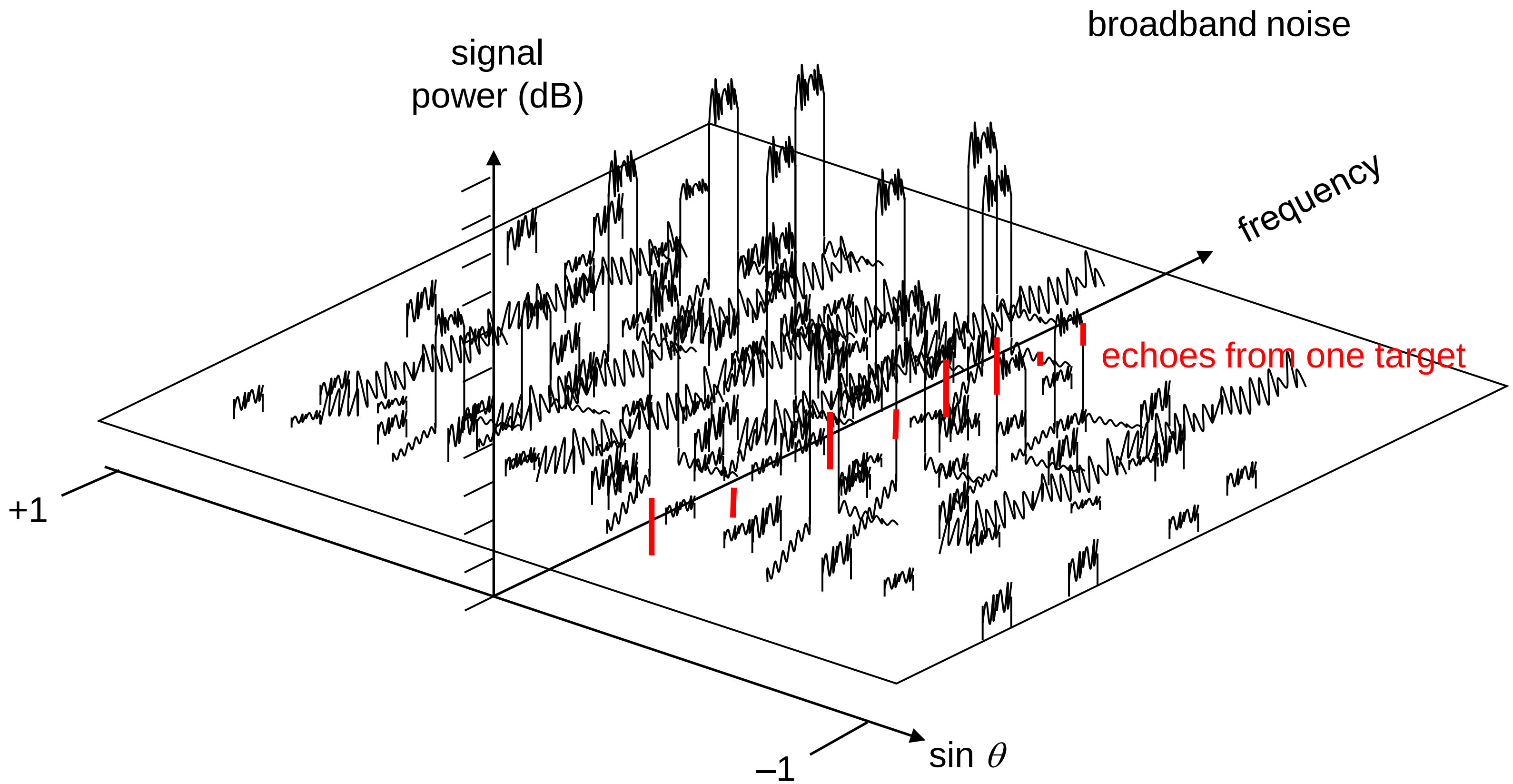
Noise and interference



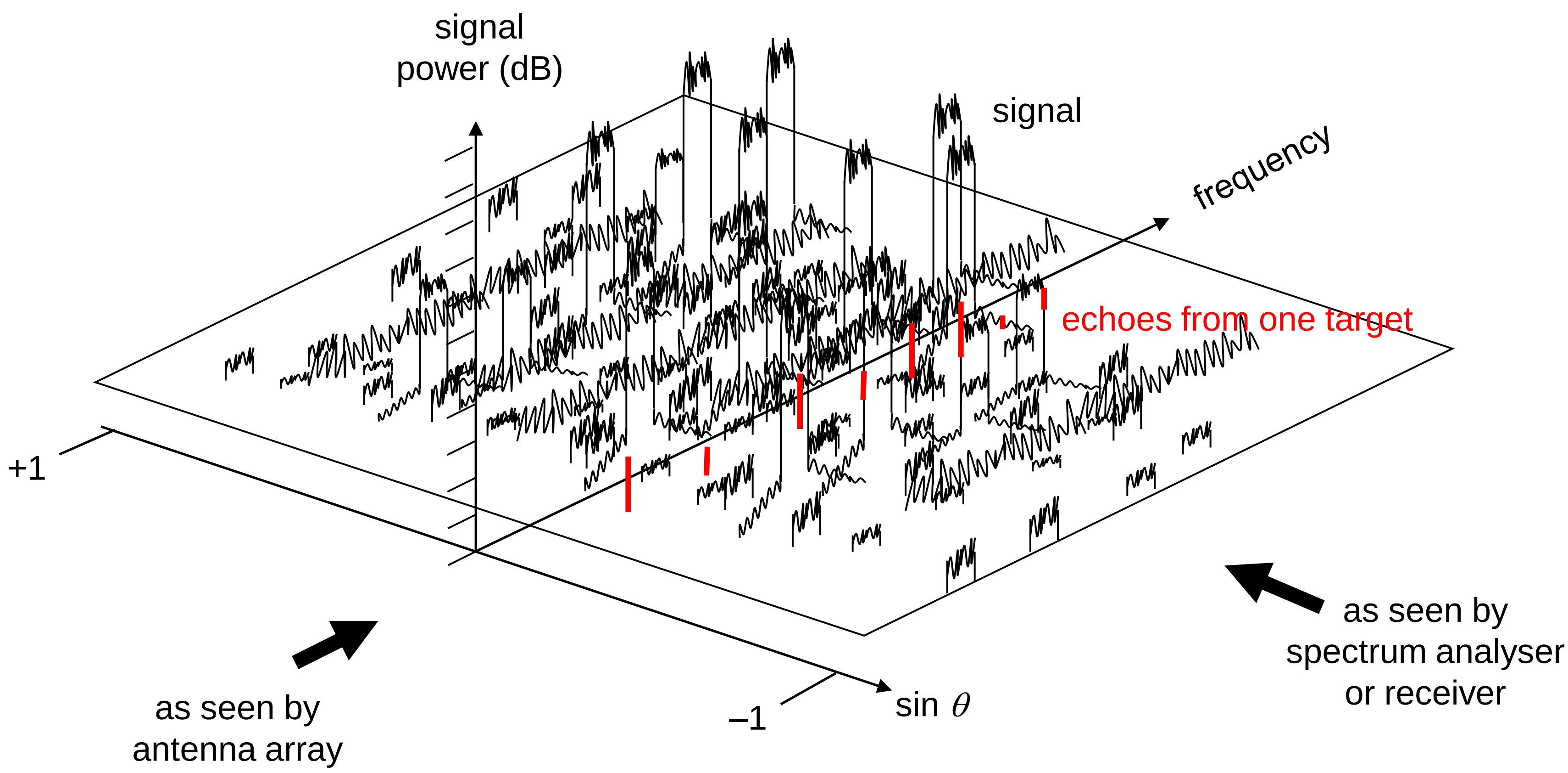
Noise and interference



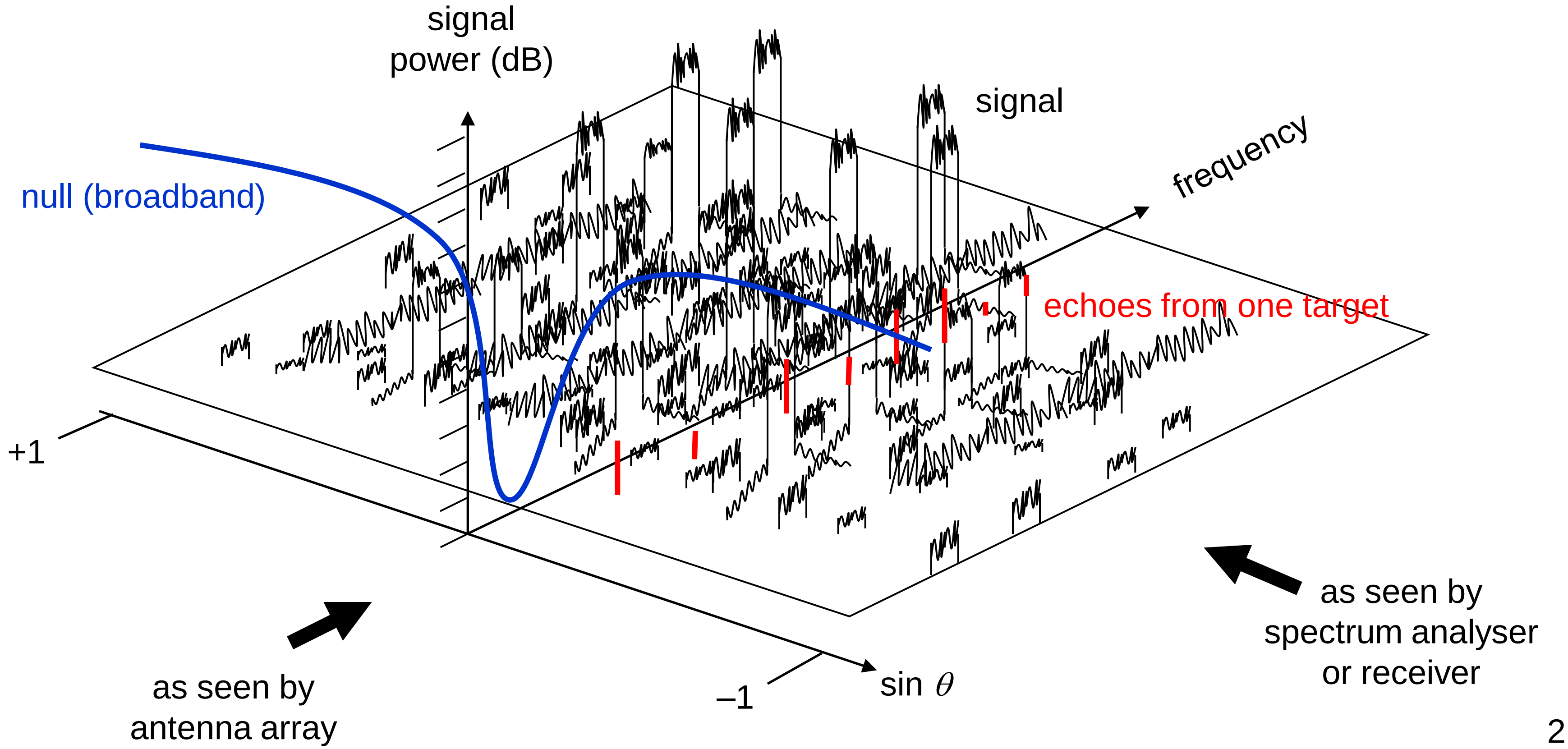
Noise and interference



Noise and interference



Noise and interference



Suppression techniques - shielding

A range of techniques may be used to attempt to suppress these signals and interference. First, and most attractive because of effectiveness, simplicity, and cost, is to site the receive antenna so that it is physically shielded from the direct path signal, using topography, buildings or shrouds. This technique alone can often provide adequate suppression, but in turn limits the receive antenna's field of view (FOV). In some cases, this trade-off is entirely acceptable. For air surveillance, terrain blockage of the receiver's FOV is nearly always unacceptable, especially for low-altitude surveillance.

However, judicious siting of the receive antenna in some geometries can still provide acceptable physical shielding. The classic example is to site the receiver (a) between the transmitter and the surveillance region with the transmitter looking *over the receiver's shoulder* and (b) with a large building or other structure located directly behind the receiver, i.e. along the baseline, to shield the direct path. As an extreme example, in the case of the Manastash Ridge Radar the receiver was located remotely, behind a mountain range and at a distance of 150 km from the transmitter, which provided more than adequate suppression of the direct transmitter signal.

Suppression techniques - cancellation

A second technique is spatial cancellation of the direct path signal. An array antenna at the receiver can be configured to steer a null at the direct path signal, and null depths of several tens of dB are achievable. Inspection of Figure 10 shows that radiation pattern nulls should ideally be broadband (in direction and depth) so that multiple signals from a given transmitter may be suppressed by a single null. Of course, an adaptive antenna and its associated signal processing introduces significant complexity, and, to some extent, negates one of the claimed advantages of PBR—that the receiver is simple and cheap.

Suppression techniques - equalisation

A third approach is to use a transversal filter equaliser method to suppress multipath in a similar way to that used in mobile communications. Two architectures that have been used with success for this purpose have been described by Howland and by Colone et al.

The former uses a two-stage adaptive noise canceller, of which the first stage is an adaptive *M*-stage lattice predictor, with prediction order $M = 50$, and the second an adaptive tapped delay line. The first is equivalent to the Gram–Schmidt algorithm and the second to a multiple regression filter. This approach was able to suppress the direct path interference by approximately 75 dB.