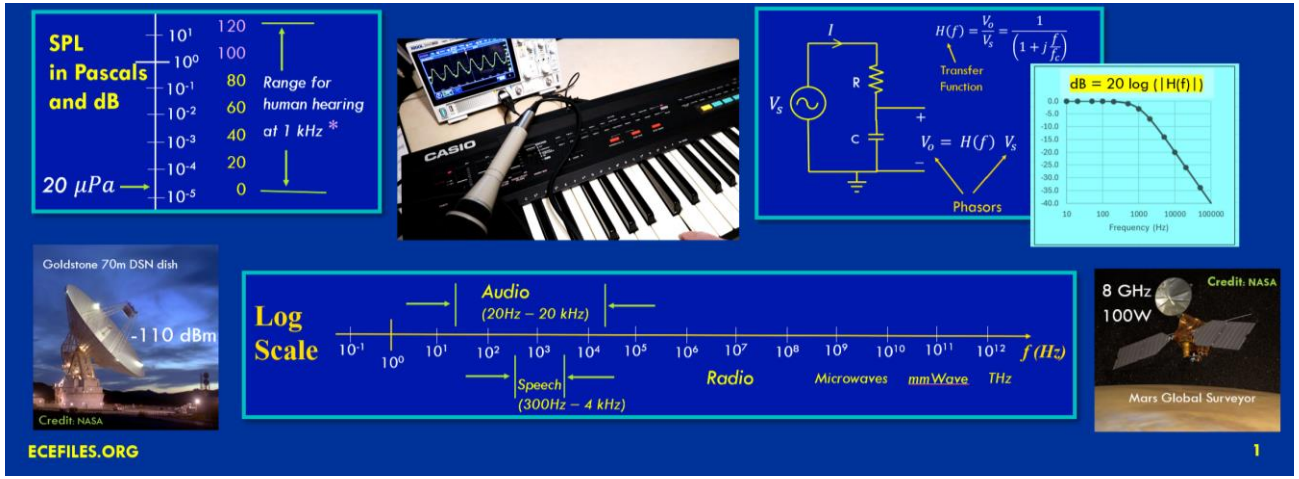
ECE Topic #7 – Frequencies, Amplitudes, Log Scales, dB and dBm

Slides downloaded from: https://ecefiles.org/ece-topics/

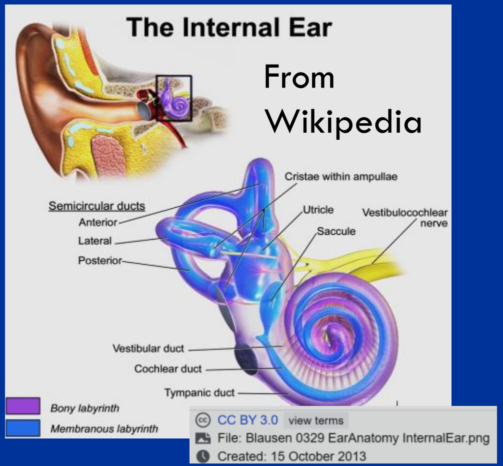
Companion video at: https://www.youtube.com/watch?v=Lg_zDBm1wa0

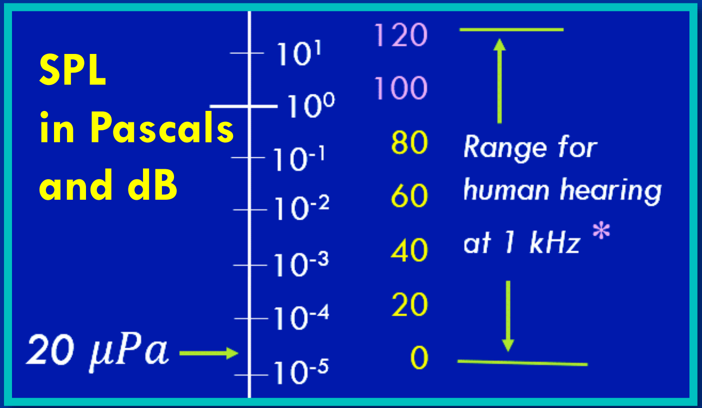
This is Episode 7 in the ECE Topics series. We cover a wide range of topics including how and why logarithmic scales are often used in frequency response graphs, and the related topics of dB and dBm. The physical world involves a wide range of frequencies and sound levels, and the processes involved result in the need to deal with orders of magnitude ranges in values. While essentially this is exponential in nature, we use logs to deal with it. Examples in the audio and radio/microwave fields are presented together with history and theory.

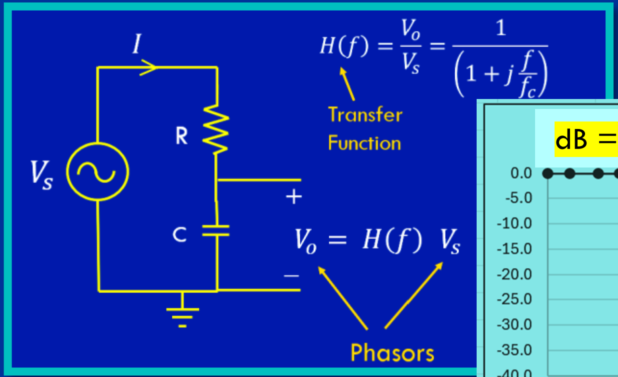


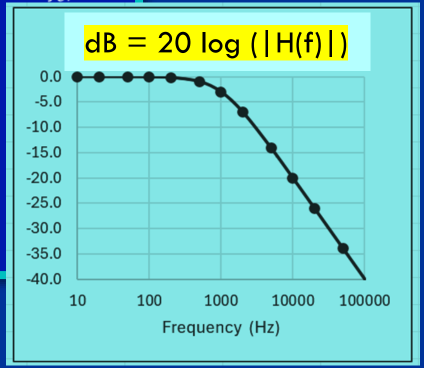
Topics in ECE #7

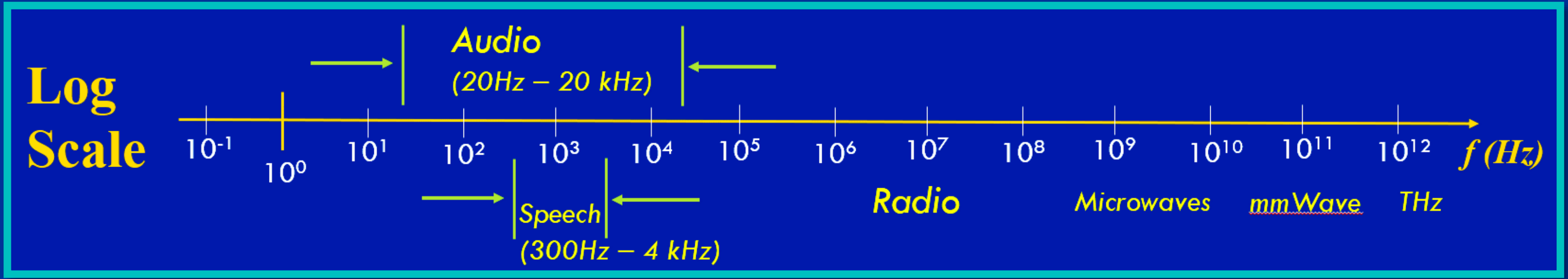
Frequencies, Amplitudes, Log Scales, dB and dBm





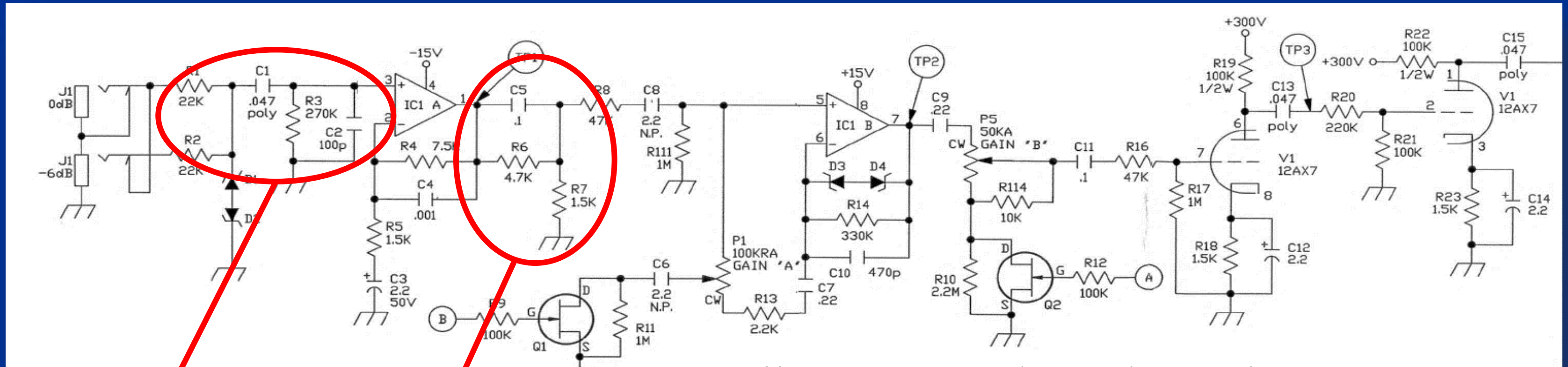




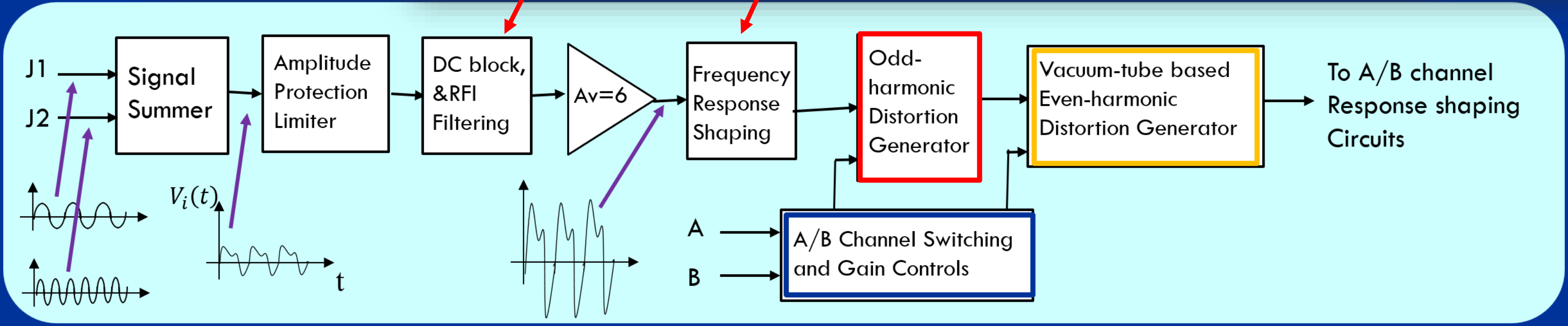


Audio Signal Processing

From ECE Topics - Episode 4 – Understanding Circuits



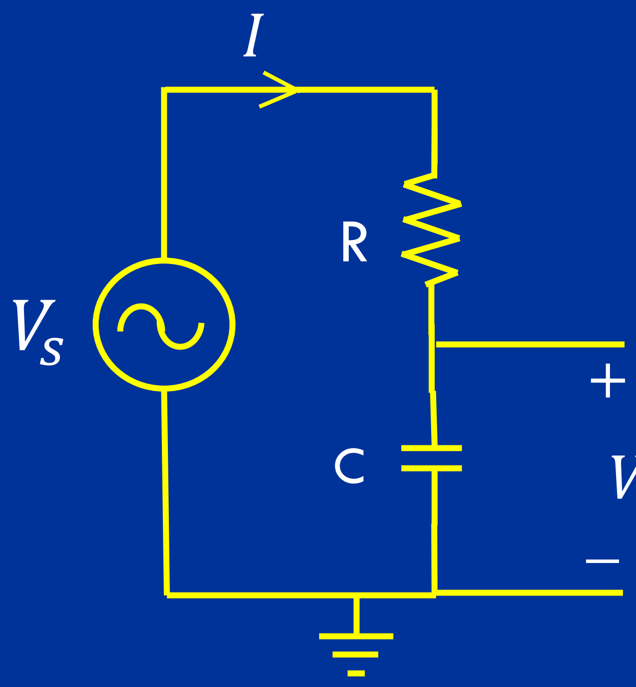
http://www.guitarnucleus.net/resources/schematics/Ampeg-AX70-Schematic.pdf



Frequency Response Plots

From Episode 6 – Complex Numbers, Phasors, …

Lowpass Filter



$$H(f) = \frac{V_o}{V_s} = \frac{1}{\left(1 + j\,\frac{f}{f_c}\right)}$$

Transfer Function

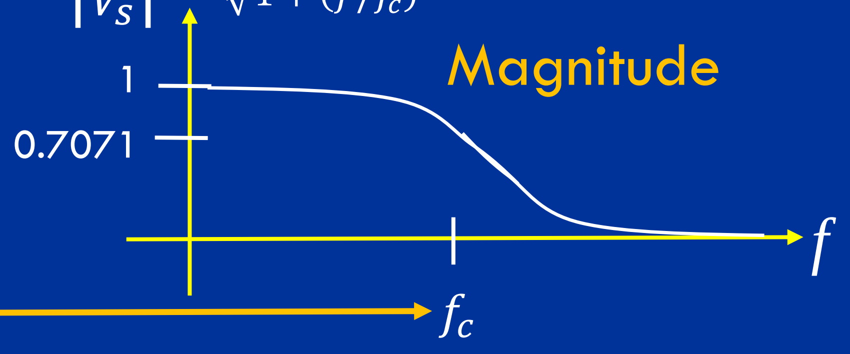
Corner Frequency

$$f_c = \frac{1}{2\pi RC}$$

$$V_o = H(f)\ V_s$$

Phasors

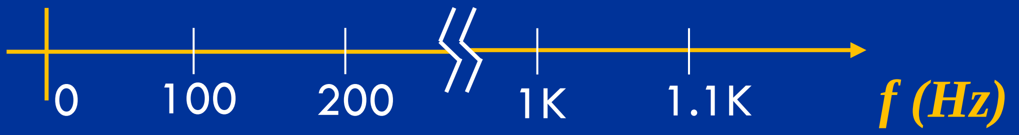
$$\left|\frac{V_o}{V_s}\right| = \frac{1}{\sqrt{1 + (f/f_c)^2}}$$



Is frequency axis linear or log-scaled here ??

Linear vs Log Scaling

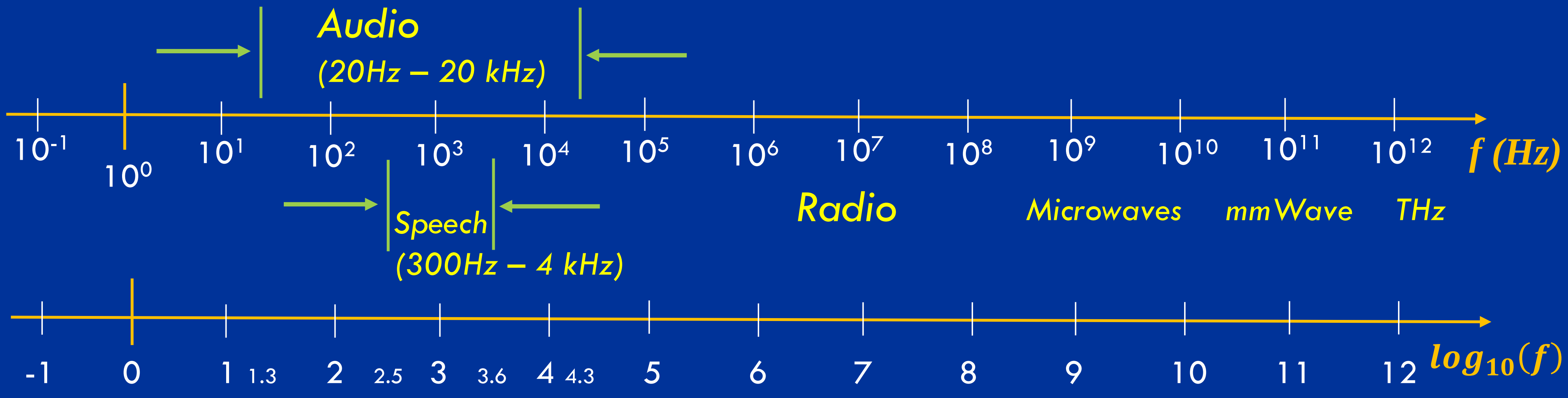
Linear Scale



Using this scale …

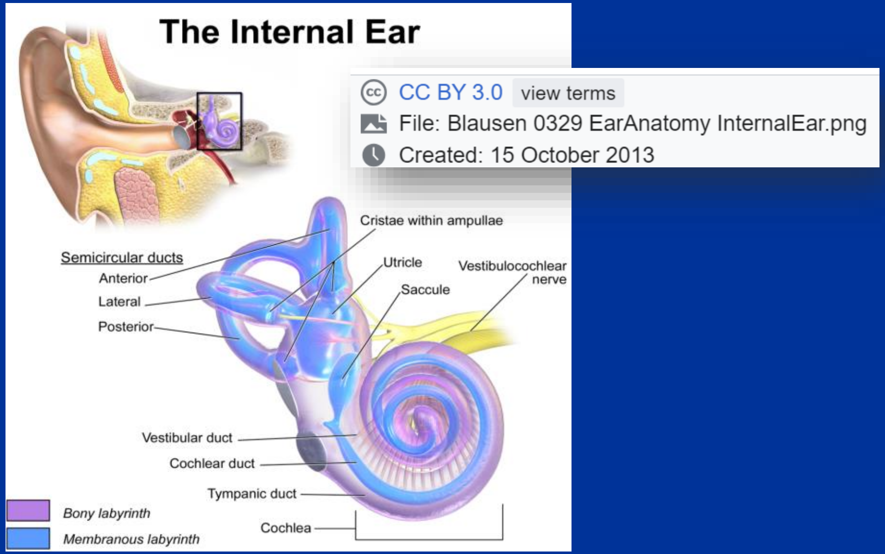
- *20 kHz is way off the page ☹*
- *2 GHz is in the next country !!*

Log Scale



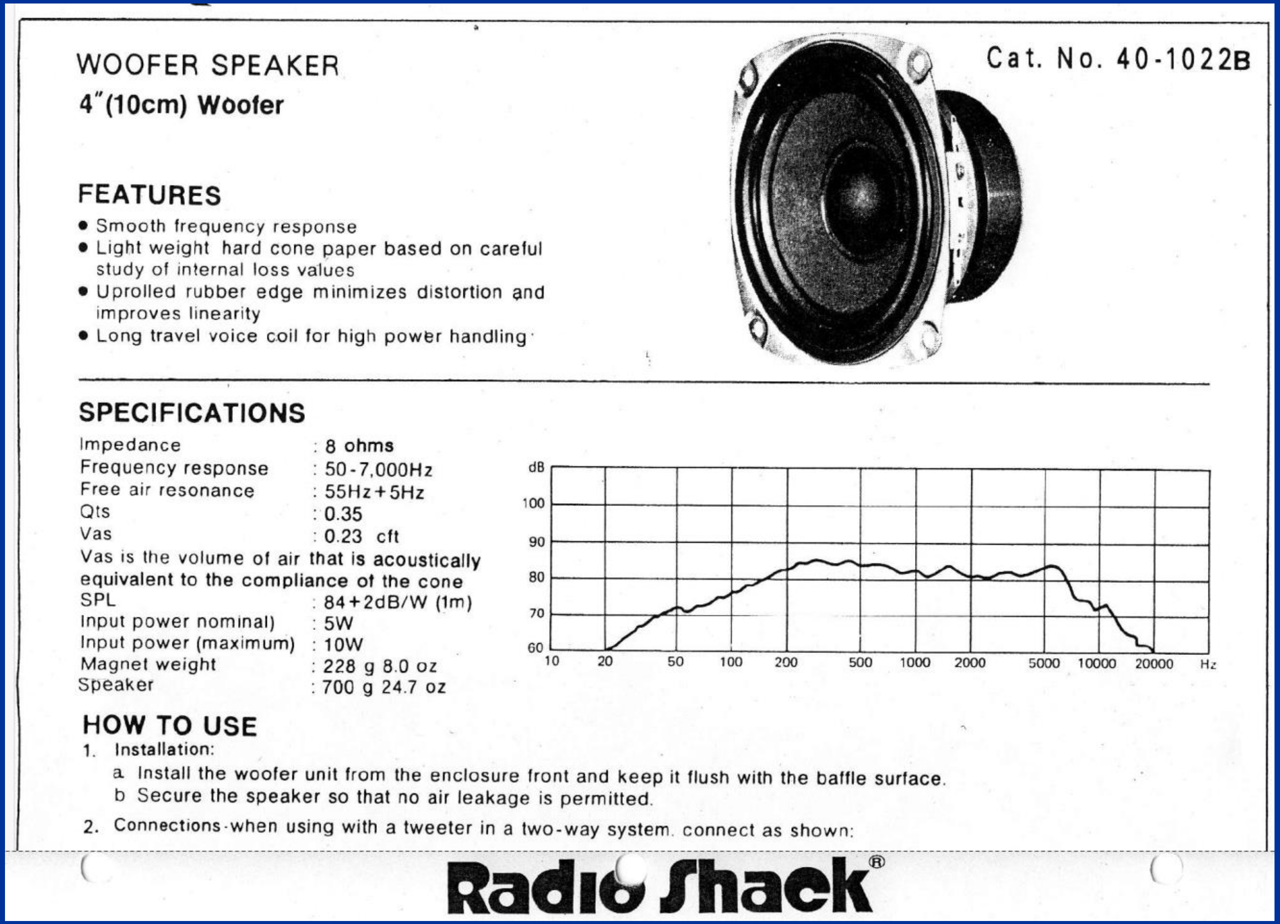
Amplitudes and dB in Audio

- *Sound pressure level (SPL) is measured in Pascals ($1\,Pa = 1\frac{N}{m^2}$)*
- *In audio, SPL is often expressed in **"dB"***
- *10 dB increase in SPL is perceived to be twice as loud*
- *SPL decreases about 6 dB for each doubling of distance*
- *Speakers typically rated at 1 meter from source at 1W*



https://en.wikipedia.org/wiki/Decibel

Example Speaker Datasheets



WOOFER SPEAKER

Cat. No. 40-1022B

4"(10cm) Woofer

FEATURES

- Smooth frequency response
- Light weight hard cone paper based on careful study of internal loss values
- Uprolled rubber edge minimizes distortion and improves linearity
- Long travel voice coil for high power handling

SPECIFICATIONS

Impedance	: 8 ohms
Frequency response	: 50-7,000Hz
Free air resonance	: 55Hz+5Hz
Qts	: 0.35
Vas	: 0.23 cft

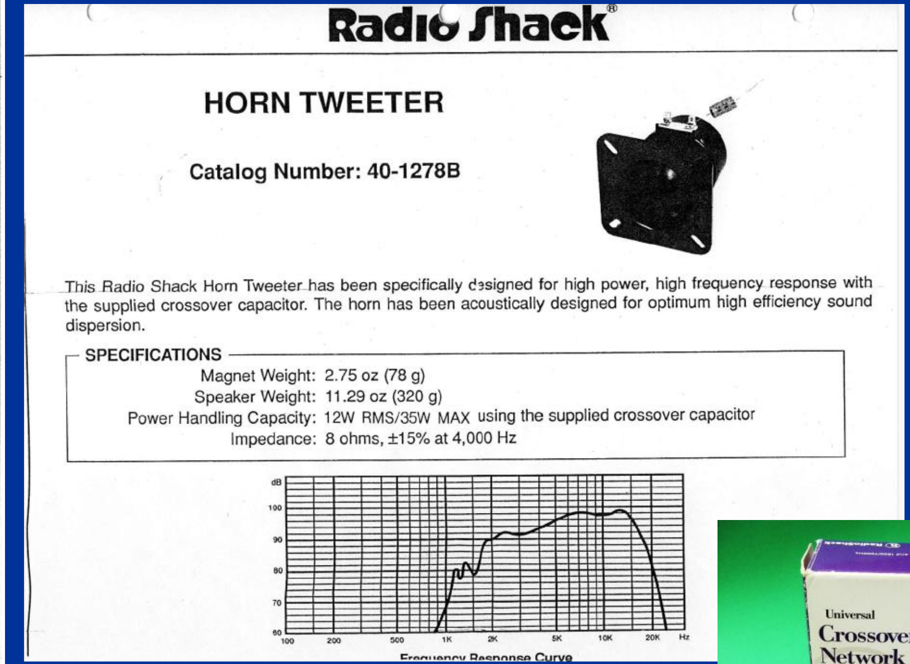
Vas is the volume of air that is acoustically equivalent to the compliance of the cone

SPL	: 84+2dB/W (1m)
Input power nominal)	: 5W
Input power (maximum)	: 10W
Magnet weight	: 228 g 8.0 oz
Speaker	: 700 g 24.7 oz

HOW TO USE

1. Installation:
   a. Install the woofer unit from the enclosure front and keep it flush with the baffle surface.
   b. Secure the speaker so that no air leakage is permitted.
2. Connections-when using with a tweeter in a two-way system. connect as shown:

Radio Shack®



Radio Shack®

HORN TWEETER

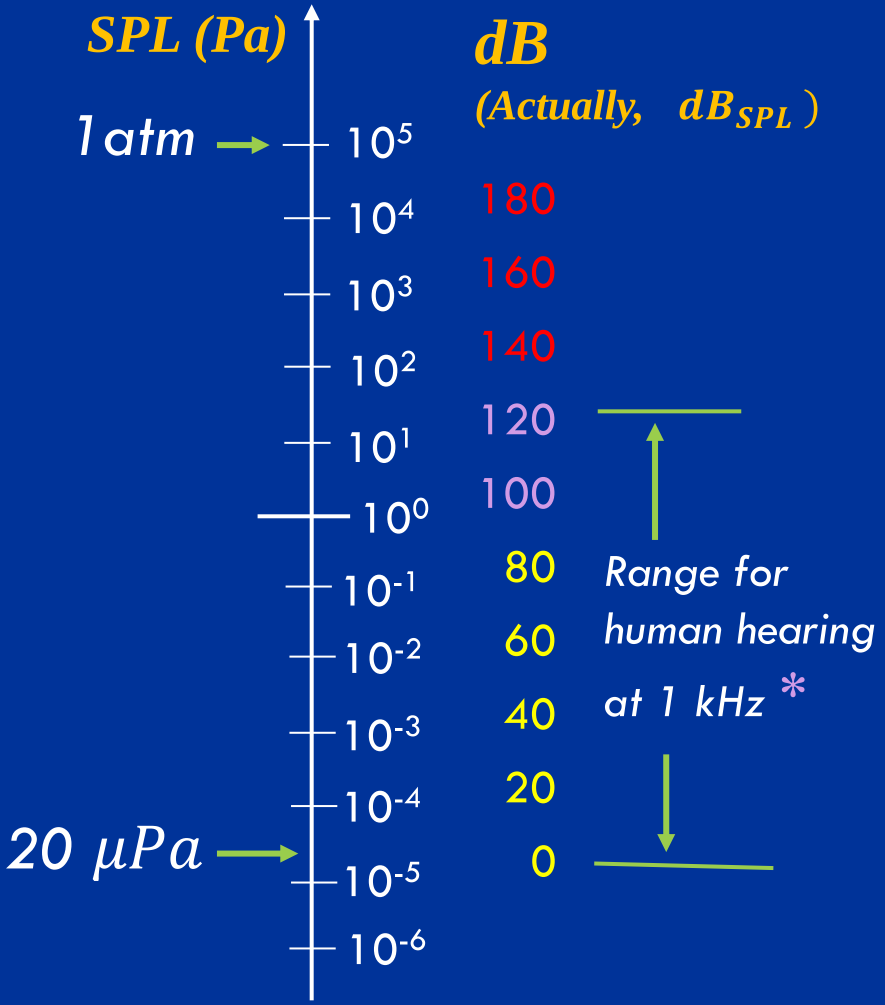
Catalog Number: 40-1278B

This Radio Shack Horn Tweeter has been specifically designed for high power, high frequency response with the supplied crossover capacitor. The horn has been acoustically designed for optimum high efficiency sound dispersion.

SPECIFICATIONS

Magnet Weight:	2.75 oz (78 g)
Speaker Weight:	11.29 oz (320 g)
Power Handling Capacity:	12W RMS/35W MAX using the supplied crossover capacitor
Impedance:	8 ohms, ±15% at 4,000 Hz

Sound Pressure Levels in dB



$$dB_{SPL} = 20\ log_{10}\left(\frac{SPL}{20\ \mu Pa}\right)$$

*** CAUTION/DANGER:**

Levels above 120 dB at ear can cause immediate hearing loss !!)

Long-term exposure above 80 or 85 dB can also cause damage

https://www.cdc.gov/nceh/hearing_loss/what_noises_cause_hearing_loss.html

References …

WIKIPEDIA
The Free Encyclopedia

Decibel

Article Talk

From Wikipedia, the free encyclopedia

https://www.cdc.gov/nceh/hearing_loss/what_noises_cause_hearing_loss.html

https://en.wikipedia.org/wiki/Decibel

Perception [edit]

The human perception of the intensity of sound and light more nearly approximates the logarithm of intensity rather than a linear relationship (see Weber–Fechner law), making the dB scale a useful measure.[28][29][30][31][32][33]

Acoustics [edit]

The decibel is commonly used in acoustics as a unit of sound power level or sound pressure level. The reference pressure for sound in air is set at the typical threshold of perception of an average human and there are common comparisons used to illustrate different levels of sound pressure. As sound pressure is a root-power quantity, the appropriate version of the unit definition is used:

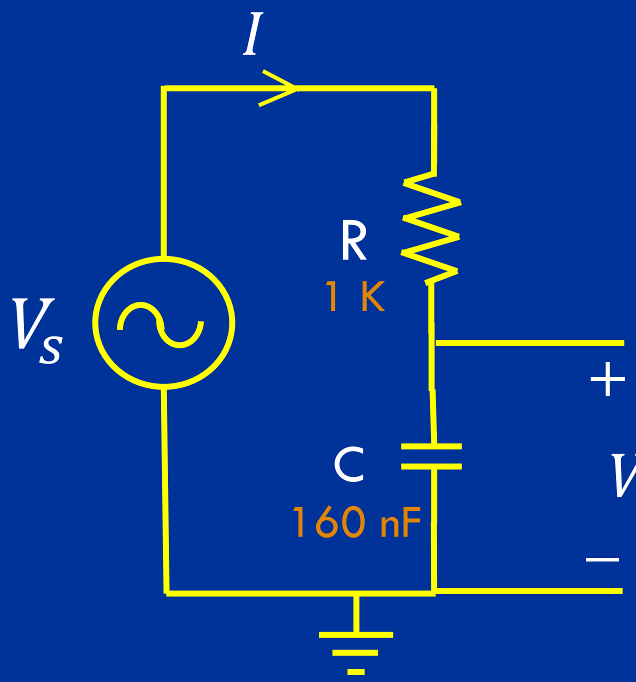
$$L_p = 20\log_{10}\left(\frac{p_{\text{rms}}}{p_{\text{ref}}}\right)\ \text{dB},$$

where p_{rms} is the root mean square of the measured sound pressure and p_{ref} is the standard reference sound pressure of 20 micropascals in air or 1 micropascal in water.[34]

Use of the decibel in underwater acoustics leads to confusion, in part because of this difference in reference value.[35][36]

dB	Power ratio	Amplitude ratio
60	1 000 000	1 000
50	100 000	316.2
40	10 000	100
30	1 000	31.62
20	100	10
10	10	3.162
6	3.981 ≈ 4	1.995 ≈ 2
3	1.995 ≈ 2	1.413 ≈ $\sqrt{2}$
1	1.259	1.122
0	1	1
−1	0.794	0.891
−3	0.501 ≈ $\frac{1}{2}$	0.708 ≈ $\sqrt{\frac{1}{2}}$
−6	0.251 ≈ $\frac{1}{4}$	0.501 ≈ $\frac{1}{2}$

Lowpass Filter
Magnitude vs Log Frequency



$$H(f) = \frac{V_o}{V_s} = \frac{1}{\left(1 + j\frac{f}{f_c}\right)}$$

Transfer Function

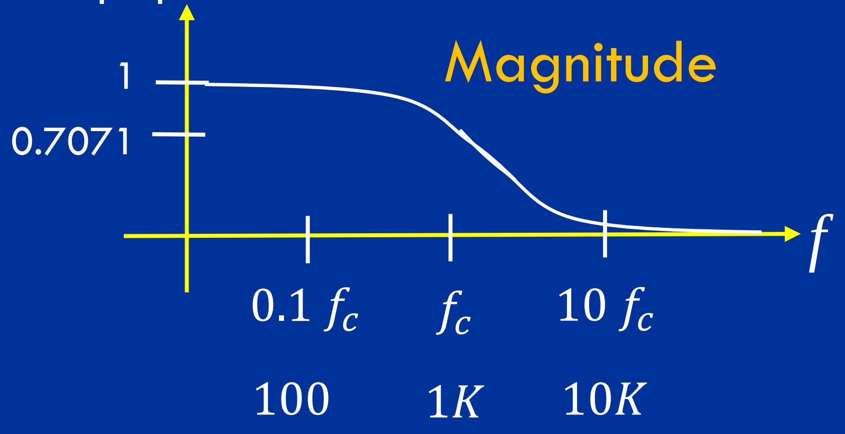
$$f_c = \frac{1}{2\pi RC}$$

= 995 Hz

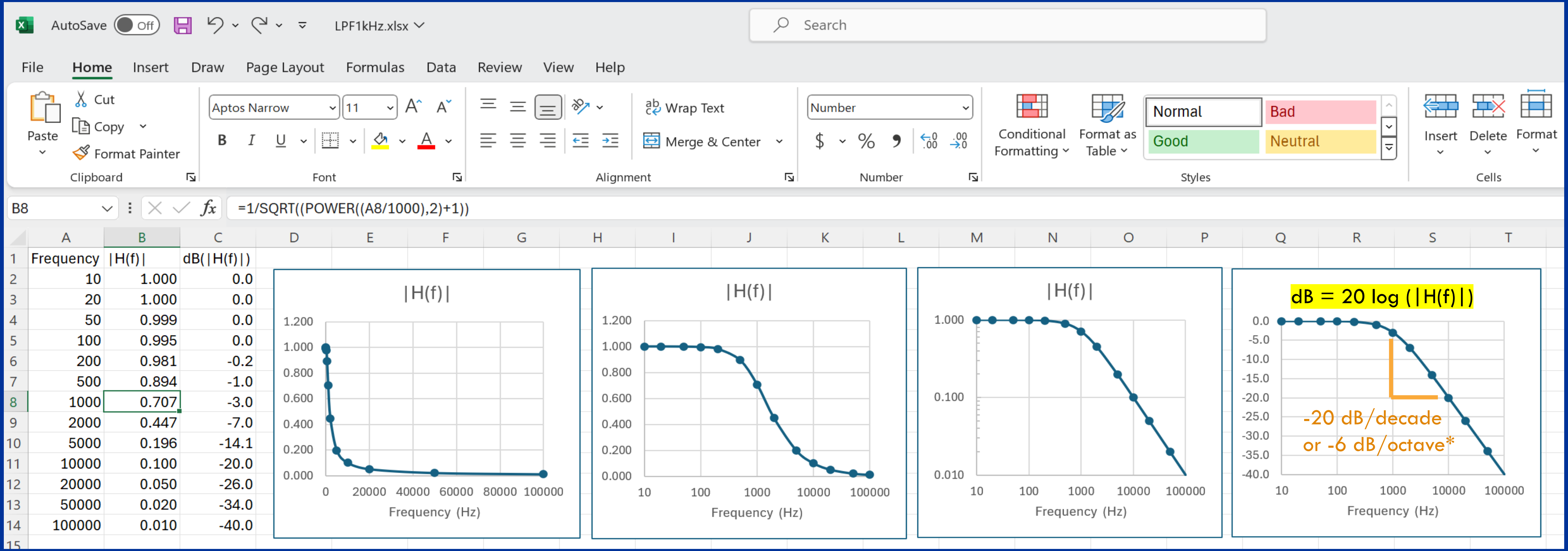
$$V_o = H(f)\ V_s$$

Phasors

$$\left|\frac{V_o}{V_s}\right| = \frac{1}{\sqrt{1 + (f/f_c)^2}}$$



Axis Scaling Choices



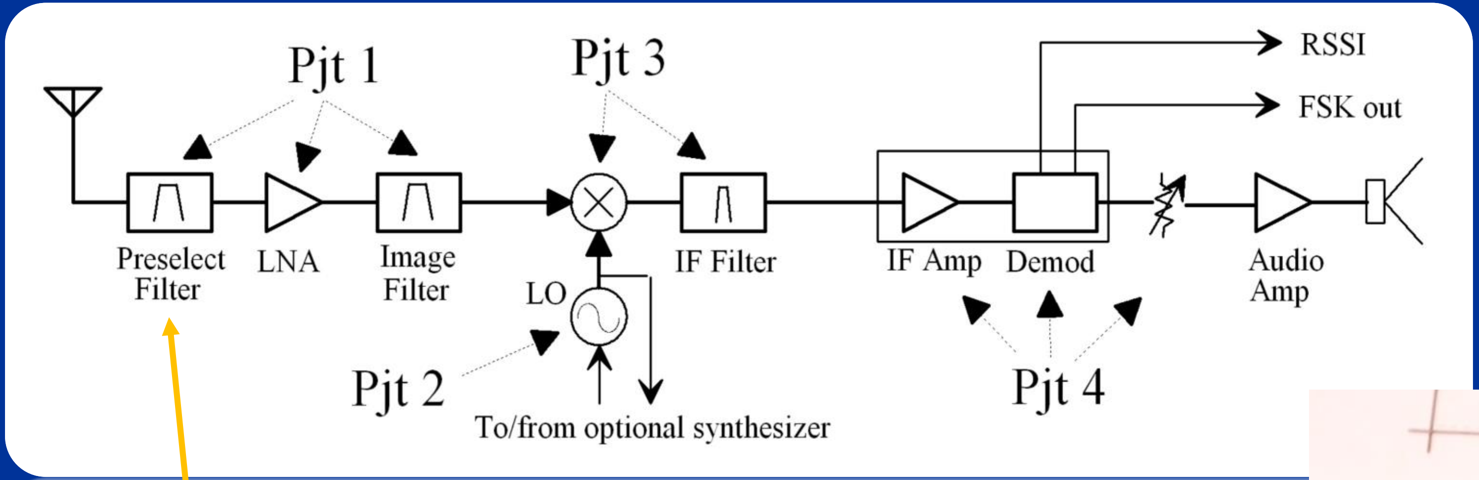
Frequency	|H(f)|	dB(|H(f)|)
10	1.000	0.0
20	1.000	0.0
50	0.999	0.0
100	0.995	0.0
200	0.981	-0.2
500	0.894	-1.0
1000	0.707	-3.0
2000	0.447	-7.0
5000	0.196	-14.1
10000	0.100	-20.0
20000	0.050	-26.0
50000	0.020	-34.0
100000	0.010	-40.0

Linear Scales | Semi-log | Log-log | Semi-log with dB

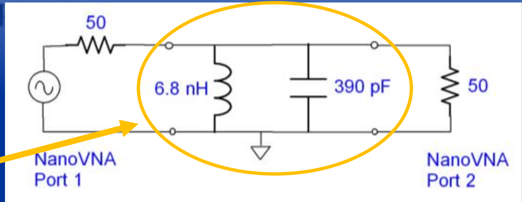
***Single-pole 1 kHz Lowpass Filter shown**

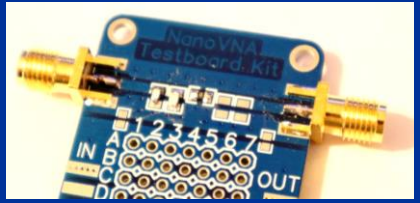
Examples at Radio Frequencies

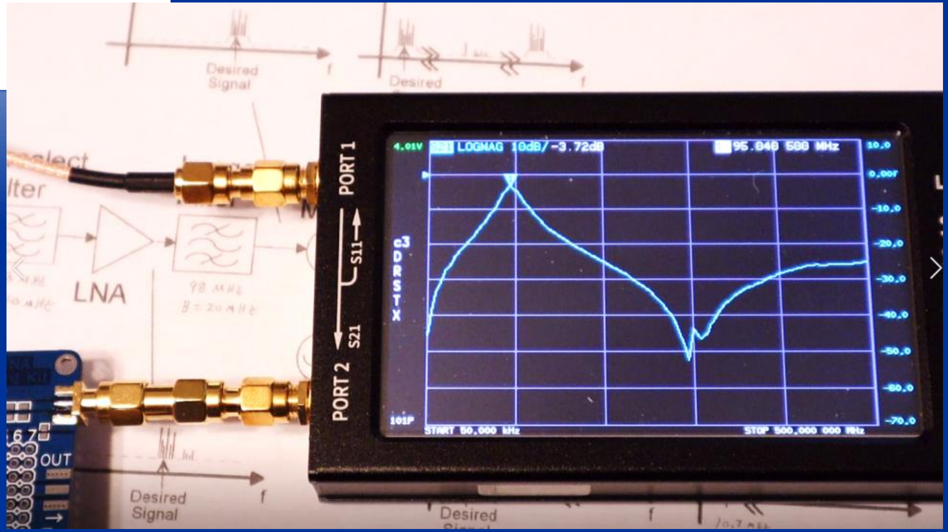
From Radio Design 101 – Episode 1



100 MHz Bandpass Filter

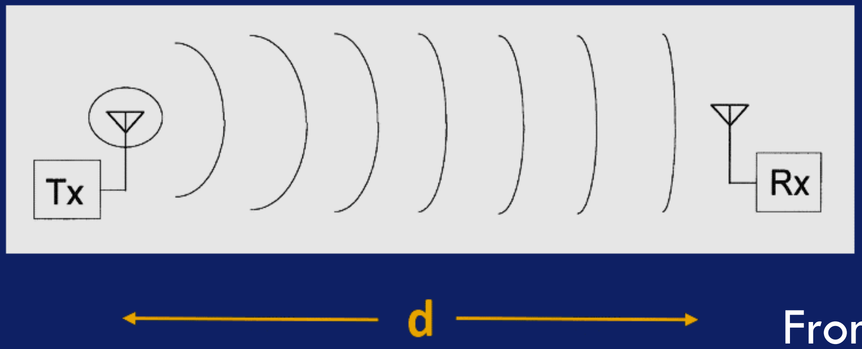






Received Levels and dB in Radio

From Antenna Briefs #3 – Maximizing Range



$$P_{density} = \frac{P_t G_t}{4\pi d^2}$$

2 for free-space
3 to 5 for terrestrial

$$P_r = P_{density}\, A_{eff-rxAnt}$$

From: Antenna Briefs Series

Received signal levels are usually expressed in ***dBm or dBuV***

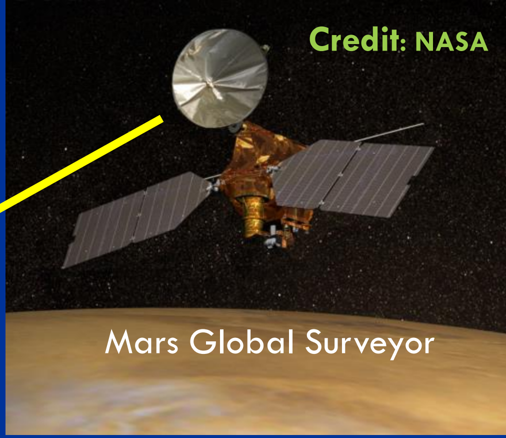
$$dB_m = 10\, log\left(\frac{Rcvd\ Power}{1\ mW}\right)$$

Use 10 when converting ***Power*** ratio to dB scale

$$dB_{\mu V} = 20\, log\left(\frac{V_{rcvd}}{1\mu V}\right)$$

Use 20 when converting ***Voltage*** ratio to dB scale

Example 1 -- Deep-Space



$$P_r = P_t \frac{G_t}{4\,\pi\, d^2} A_{eff-rxAnt}$$

230 Million Miles

Rough estimates based on web search results:

Downlink frequency 8.4 GHz
Transmit dish diameter: 3 m
Receiver dish diameter: 70 m
Earth-Mars distance (max): 378 M km

P_t = 100 W
$\lambda = 0.036\ m$
G_t=50,000 (@ 70% aperture efficiency)
d_{max}=378E9 m
A_{eff}=3800 m^2

$P_r =$ 1.1E-14 W
(-110 dBm)

Example 2 -- Terrestrial Links (Measured)

$$P_r = P_t \, G_t \, \frac{1}{4\,\pi\, d^n} \, A_{eff}$$

n = 3 to 5 !

Pt = 10 mW (+10 dBm)

Gt = 1.6 to 10 (Gt and A_{eff} depend on antenna)

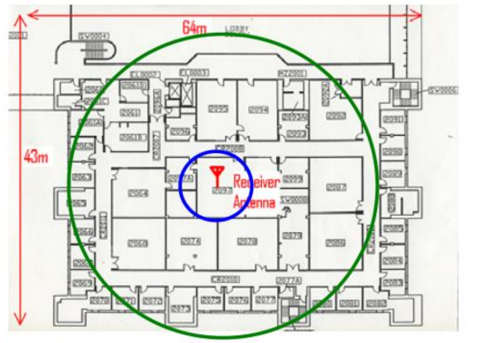


Figure I. Indoor propagation testing environment.

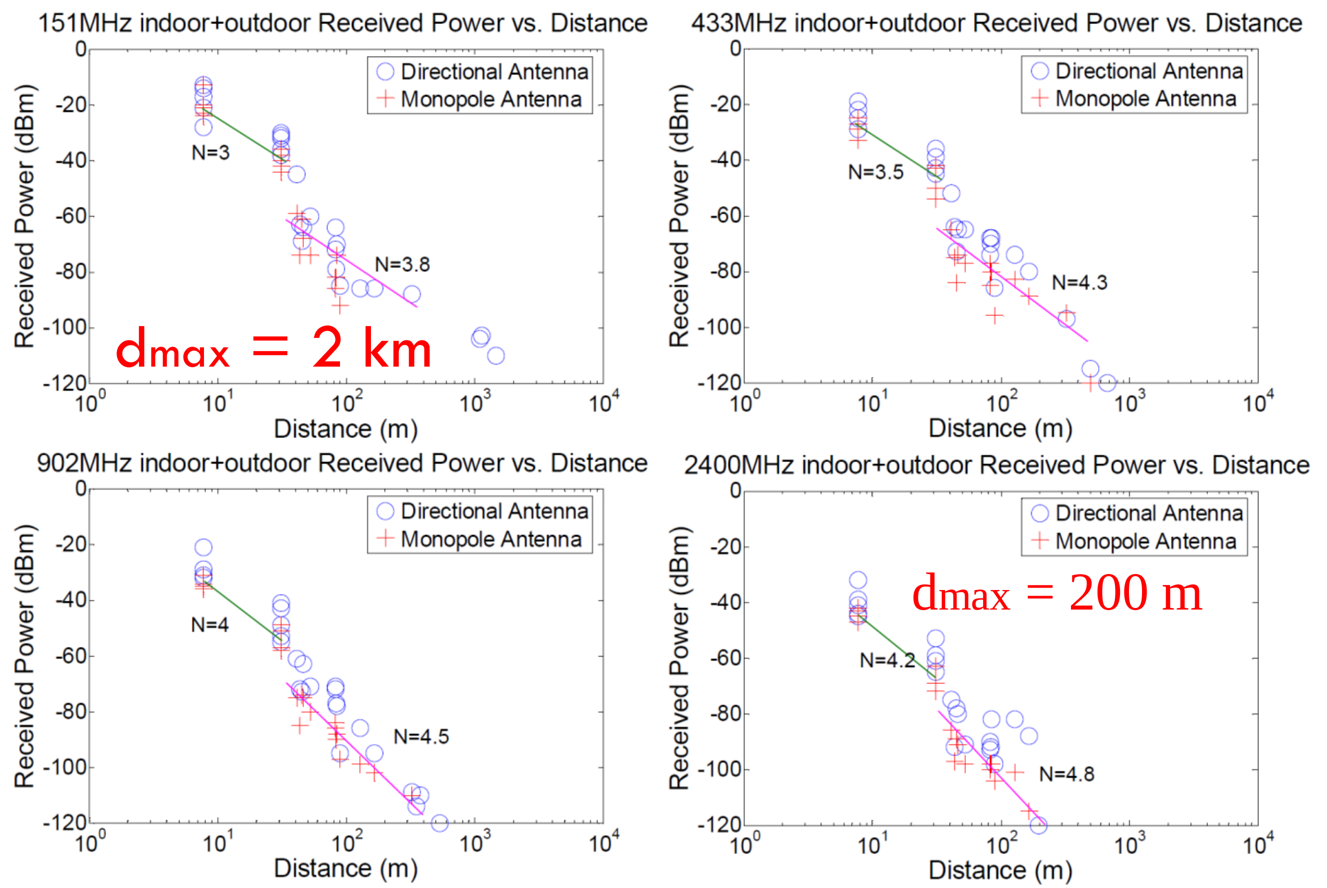
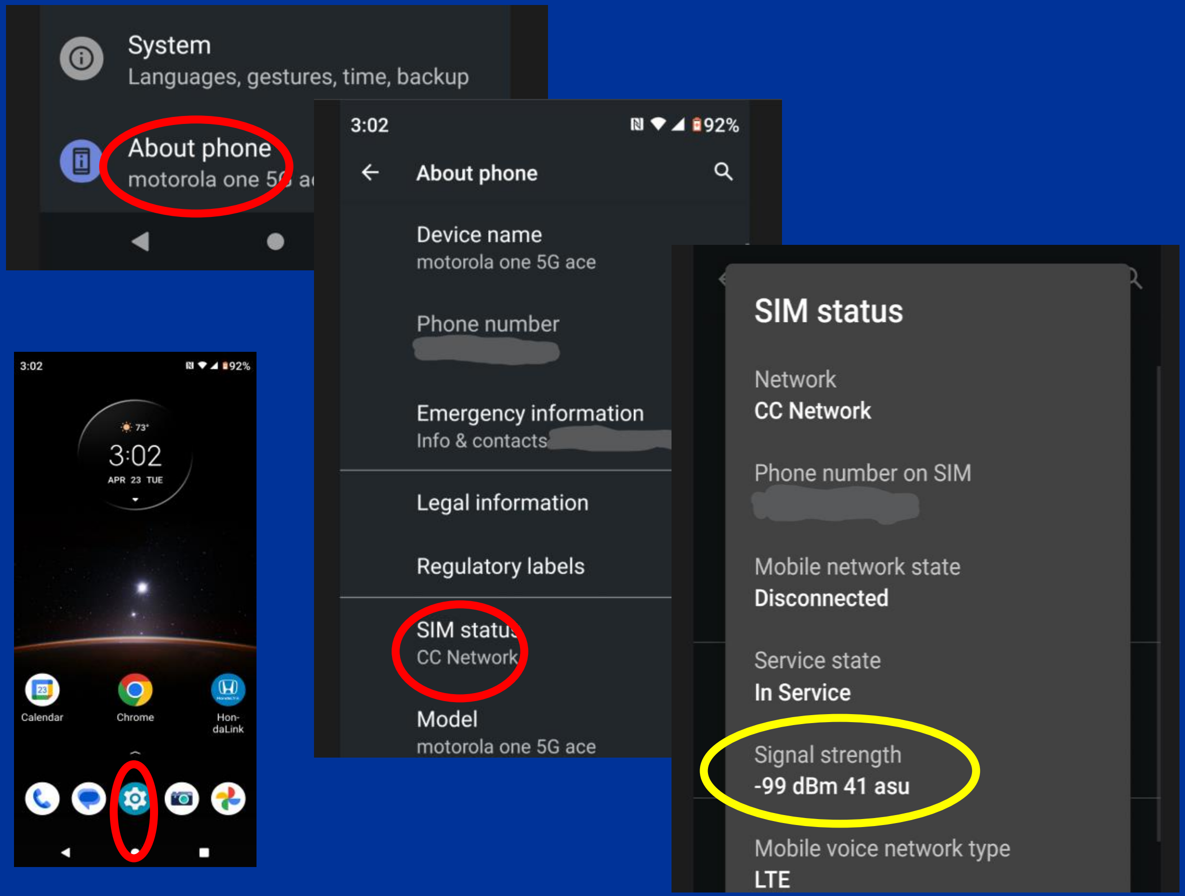
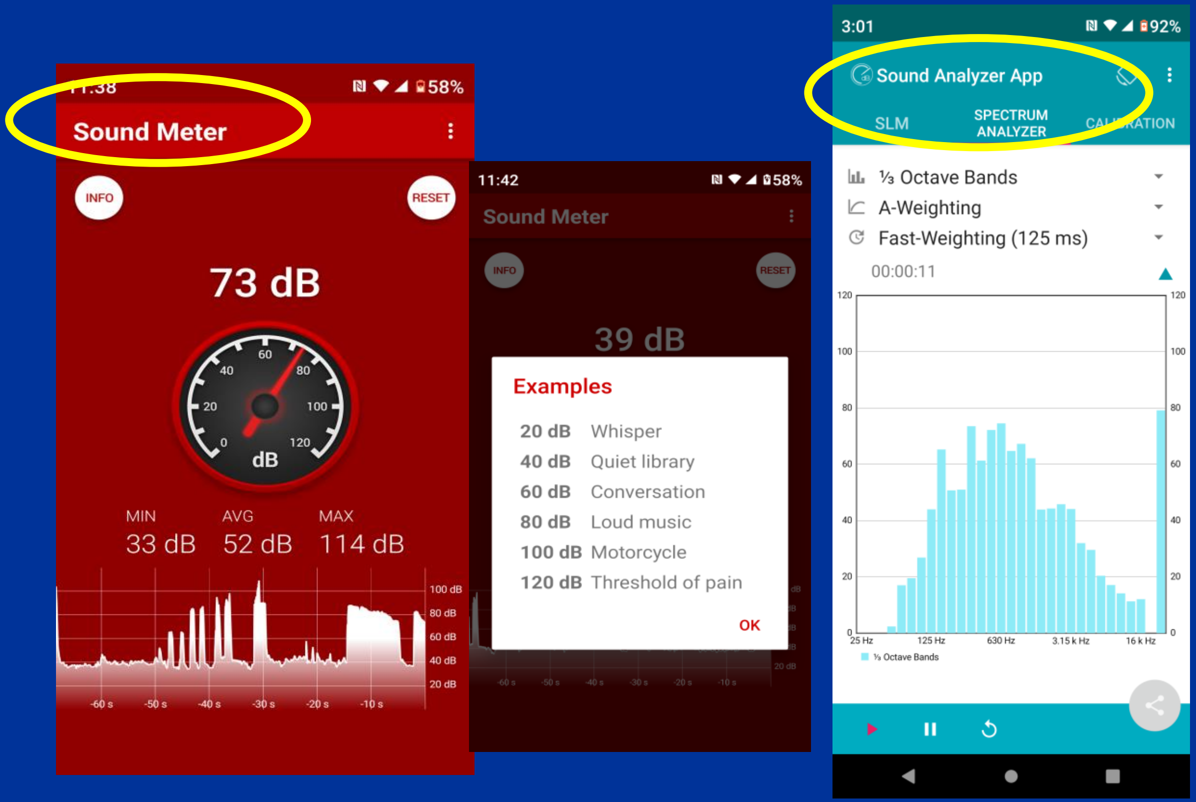


Figure V Four frequencies comparison with Path loss Exponent

From: "Propagation comparisons at VHF and UHF frequencies," 2009 IEEE Radio and Wireless Symposium

Cell Phones ☺





CAUTION: Some apps may be inaccurate

Especially with loud sounds…

Thanks for Watching !