

TECHNICAL AND POLICY CONSIDERATIONS FOR BROADBAND POWERLINE (BPL) COMMUNICATION (2 – 30 MHz)

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Advantages of BPL

- no new infrastructure is required
- the power system is everywhere

Technical Challenges

- reduce attenuation due to taps and connected elements
- overcome high background noise due to induced broadcast signals
- reduce emissions to below legal limits

The BIG Question

Do attenuation, background noise and restricted input power due to emission limits result in the need for financial investment (i.e., for additional equipment, system conditioning, or maintenance) that is incompatible with the requirement that the system be profitable?

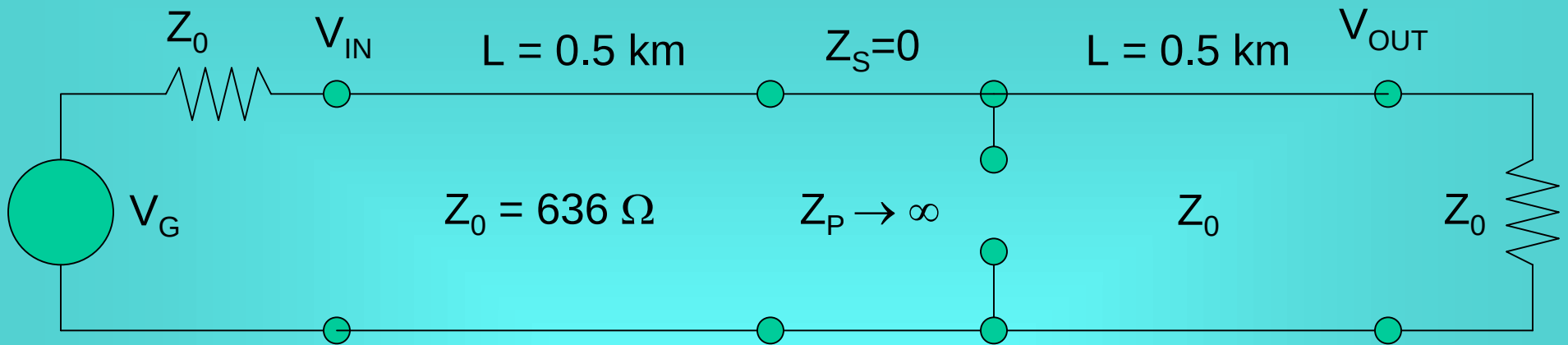
This question may be answered by reducing installation/operating cost or increasing income by adding customers or services or both.

Attenuation

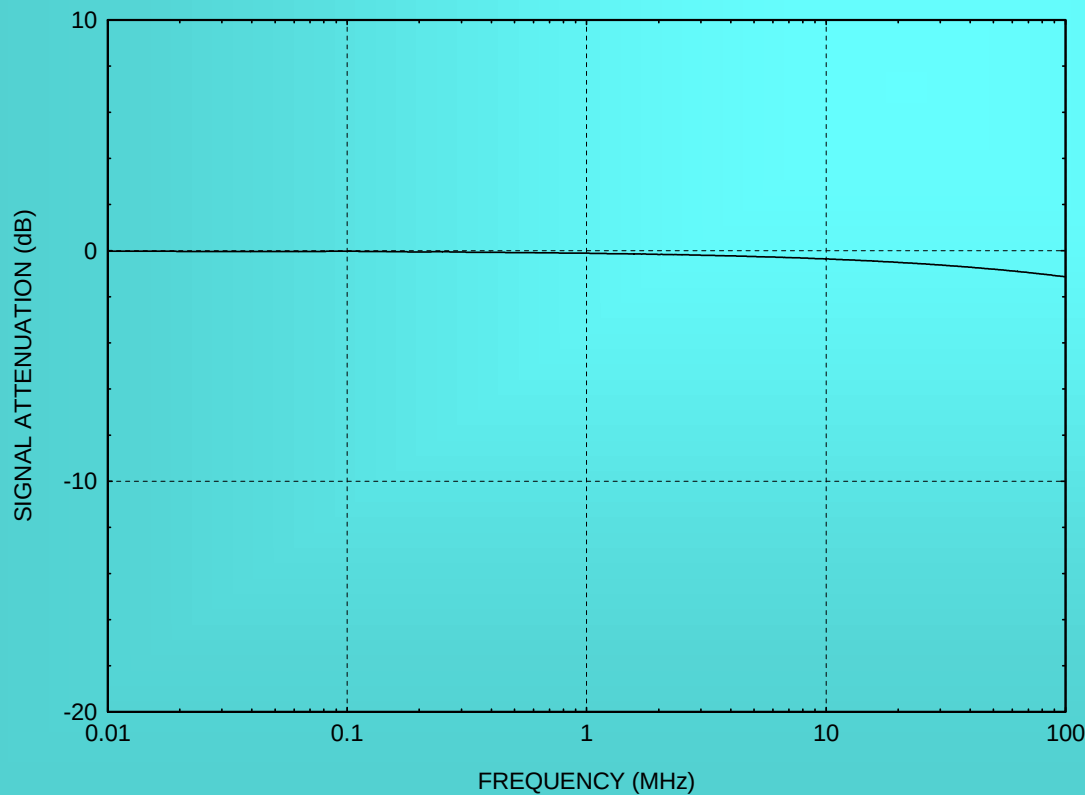
Typical calculated high frequency (2-30 MHz) attenuations for simple power line geometries are < 0.5 dB/km.

Measured attenuations in 2 – 30 MHz range are very frequency dependent and suggest attenuation rates of 10 - 40 dB/km. These are significantly higher than those calculated. The reason for this will be discussed next.

Simple System



copper wire line, wire radius = $a = 0.5$ cm, spacing = $d = 1.0$ m

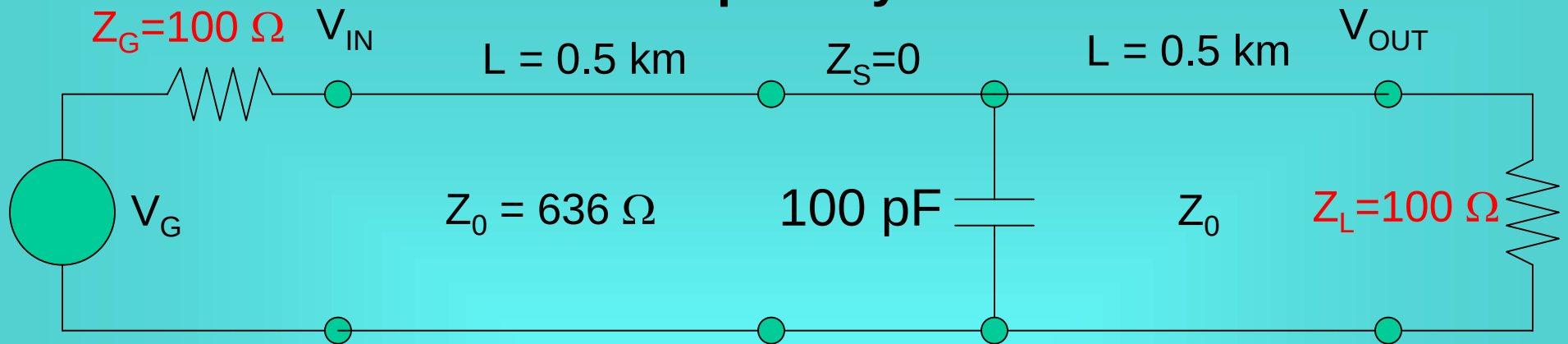


Simple, matched line gives very low attenuation

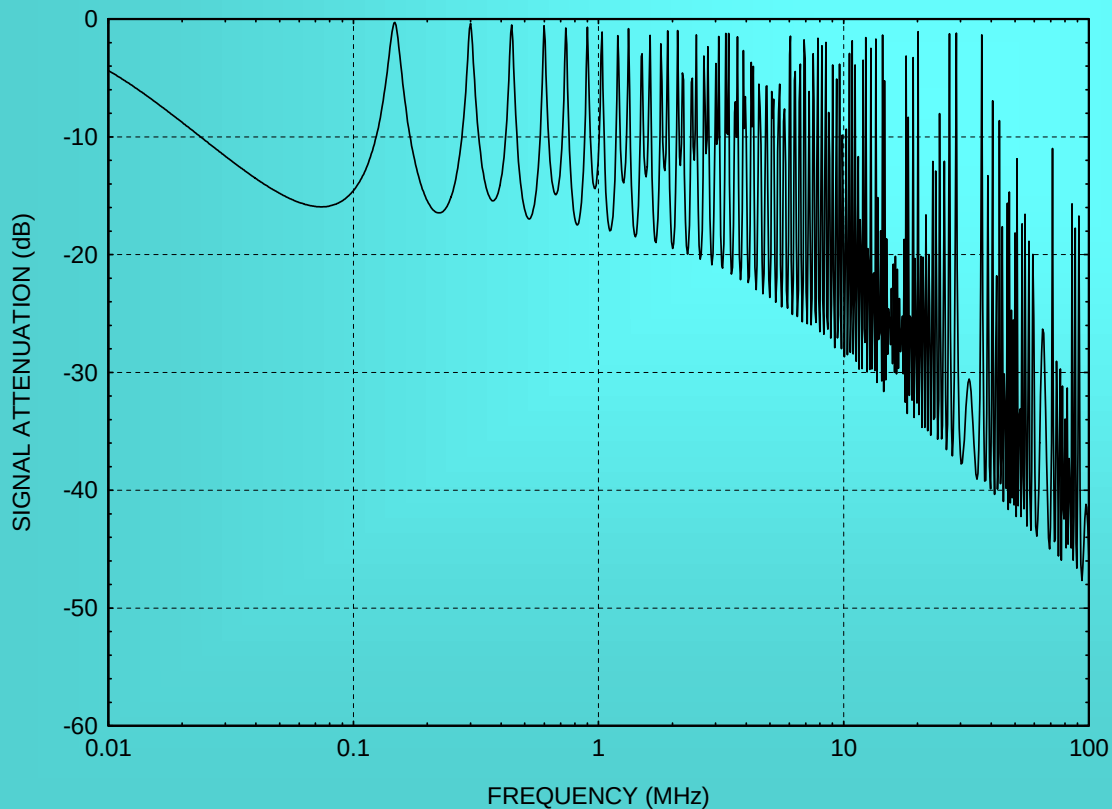
Much lower than observed

Why?

Complex System



copper wire line, wire radius = $a = 0.5 \text{ cm}$, spacing = $d = 1.0 \text{ m}$



Adding mismatched generator, load, and parallel capacitor increases the attenuation at higher frequencies

Attenuation can exceed 15 dB at low frequencies and 40 dB at higher frequencies

Other Sources of Attenuation

- Changes in line type (e.g., overhead to underground transitions)
- Taps and/or junctions
- Connected devices (e.g., transformers)

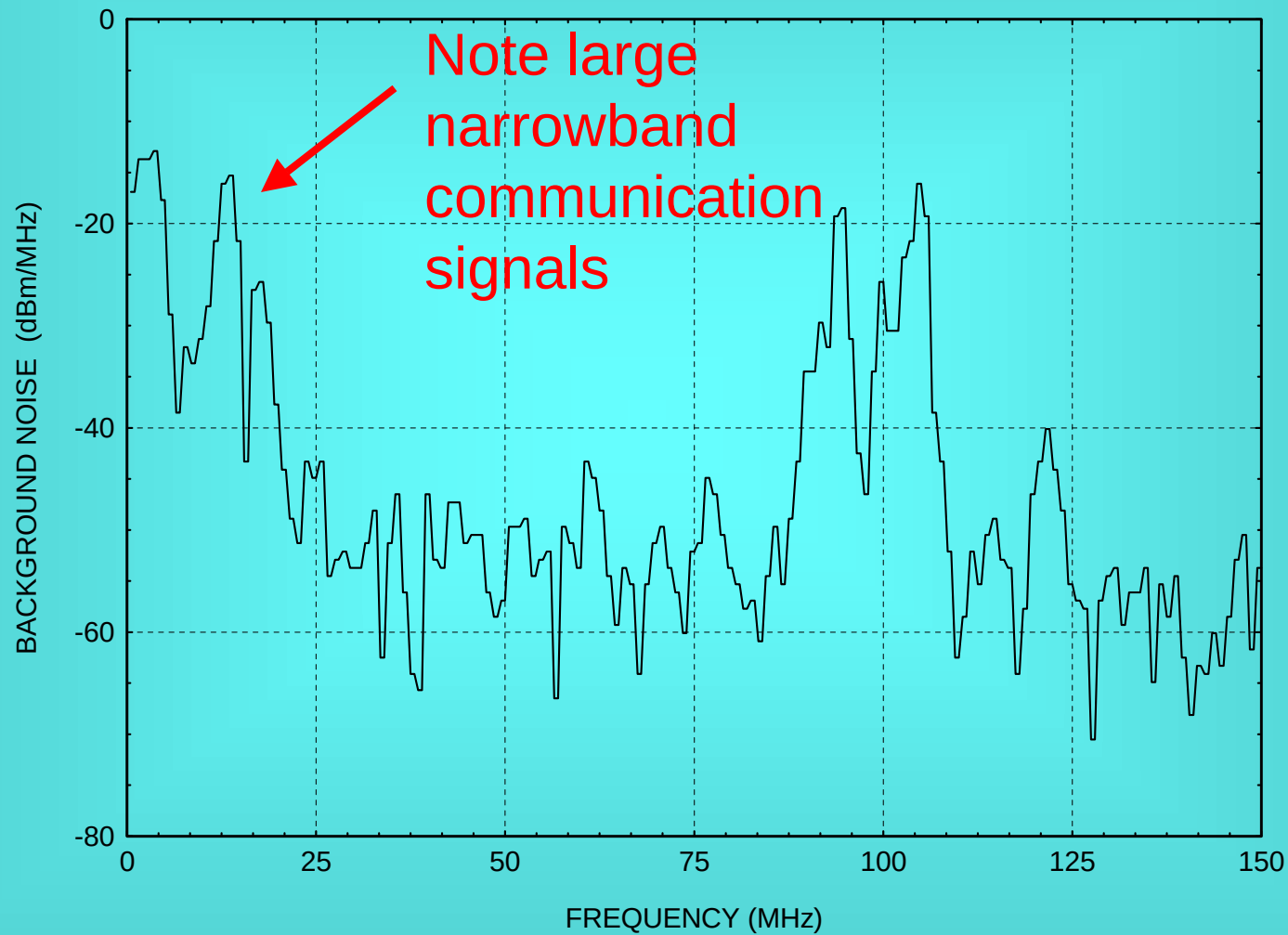
Background Noise

A number of sources that may cause noise in the 2 – 30 MHz frequency range including:

- Corona/microsparks
- Appliances with universal motors
- Lightning
- Other communication signals – the big one

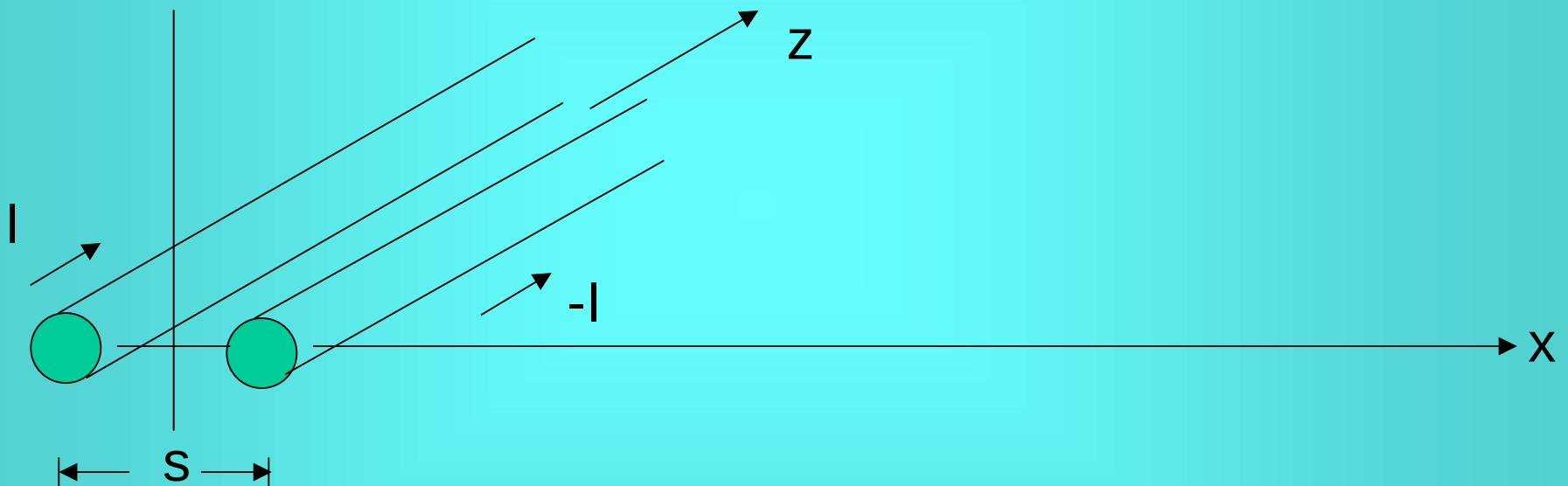
The noise level will generally be time varying.

Example of Measured Noise on a Distribution Line



Electromagnetic Emissions

Consider the fields from **balanced currents** in a pair of parallel conductors



$$E_{\text{equivalent}} = 20 \log_{10} \left(\frac{60Is}{x^2 + (s/2)^2} \right) \cong 20 \log_{10} \left(\frac{60Is}{x^2} \right), \quad x \gg s$$

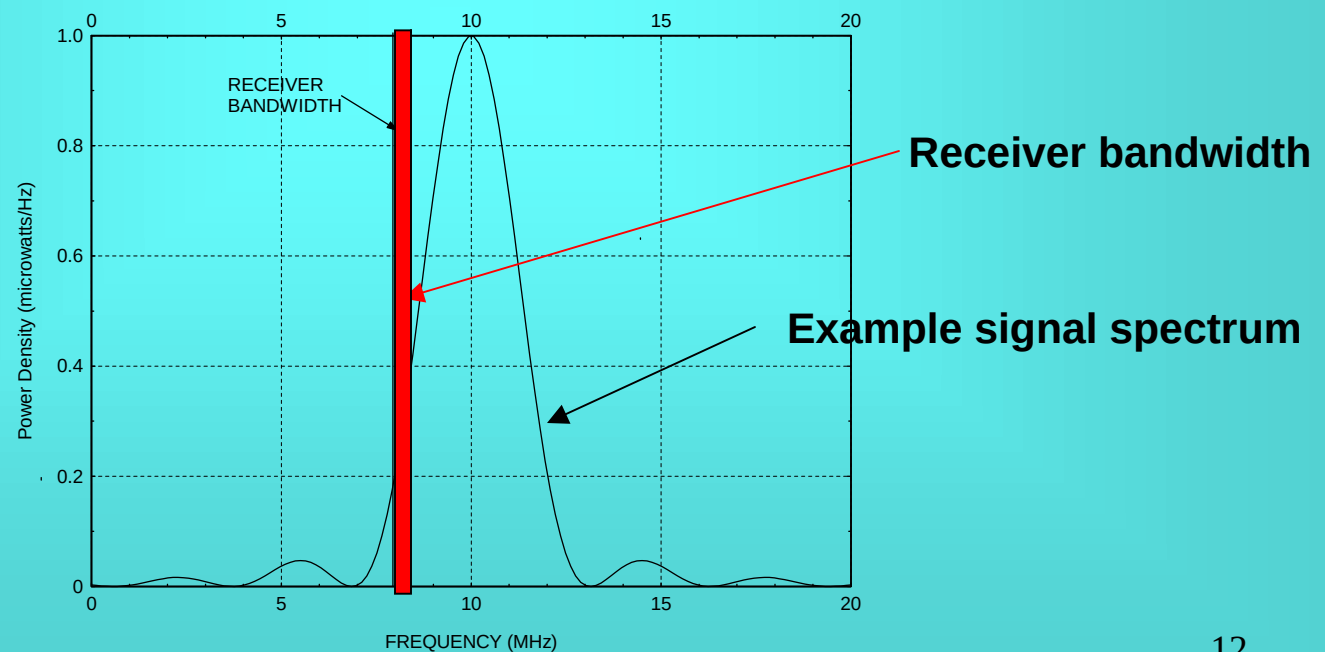
Maximum allowable transmitter power?

If $s = 1$ meter, the sinusoidal current required to produce a 50 dB $\mu\text{V}/\text{m}$ equivalent electric field (i.e., the FCC limit) at $x = 3$ meters is 47 μA !

If $Z_0 = 550\Omega$, then **the maximum power** flowing (without violating the FCC limit) on the power line is **1.21 μW or -29 dBm!** **This is not much!**

Good News for BPL - using broadband signals helps

Spreading the signal over a wide bandwidth does allow increased total power since the receiver required by the standards is narrowband (i.e., 9 kHz). It, thus, measures only the portion of the total power within its bandwidth



Bad News for BPL

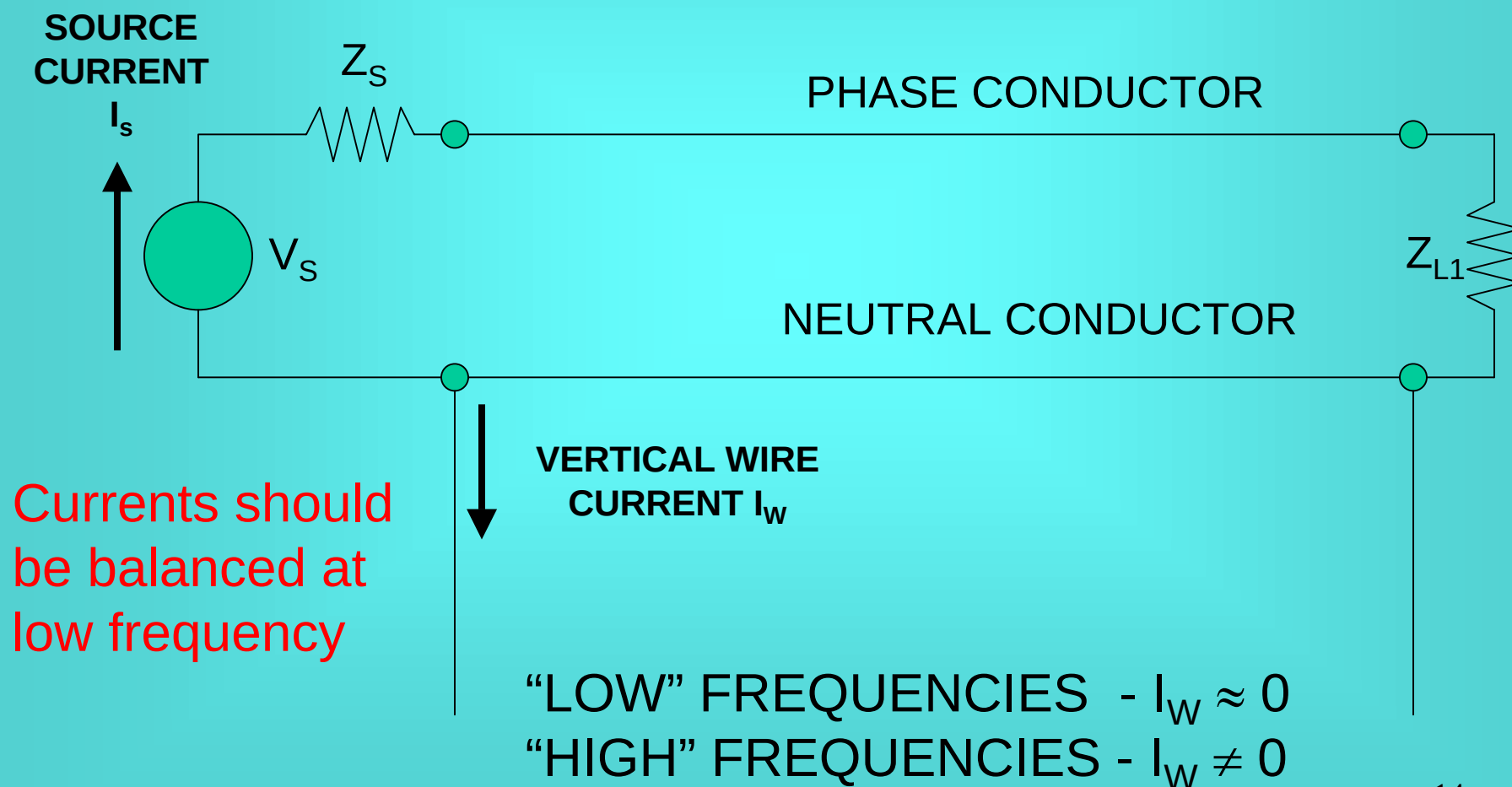
Unbalanced systems increase emissions

- Earlier calculations assumed balanced currents
- The unsymmetric geometry of electric power lines is a cause of unbalanced (common mode) currents
- Emissions from unbalanced currents on a power line are greater than those from balanced currents on the same power line

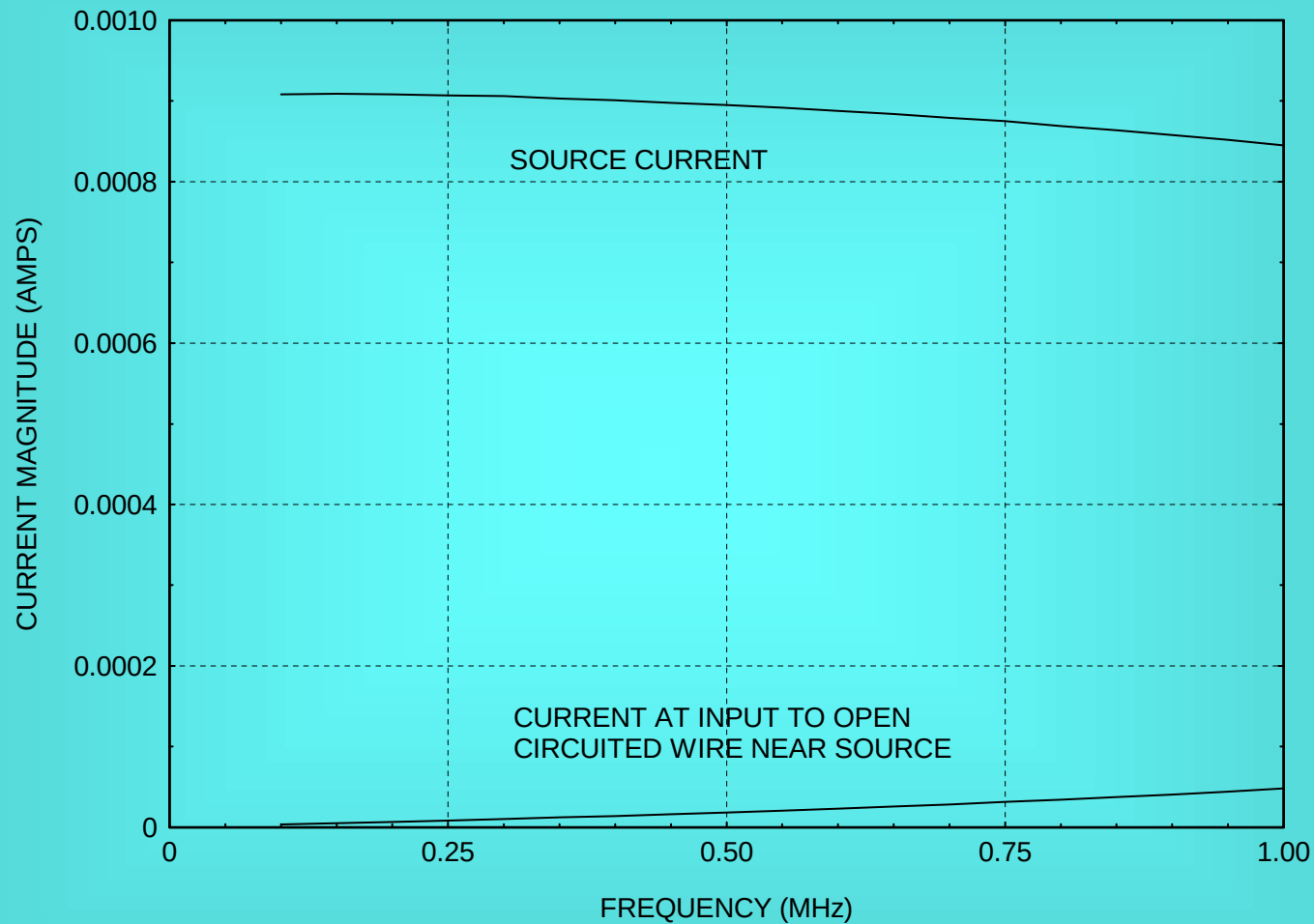
Effect of unbalance - simple distribution system

(Might represent ground wires or light poles connected to system.)

Solved using the MININEC antenna theory program.

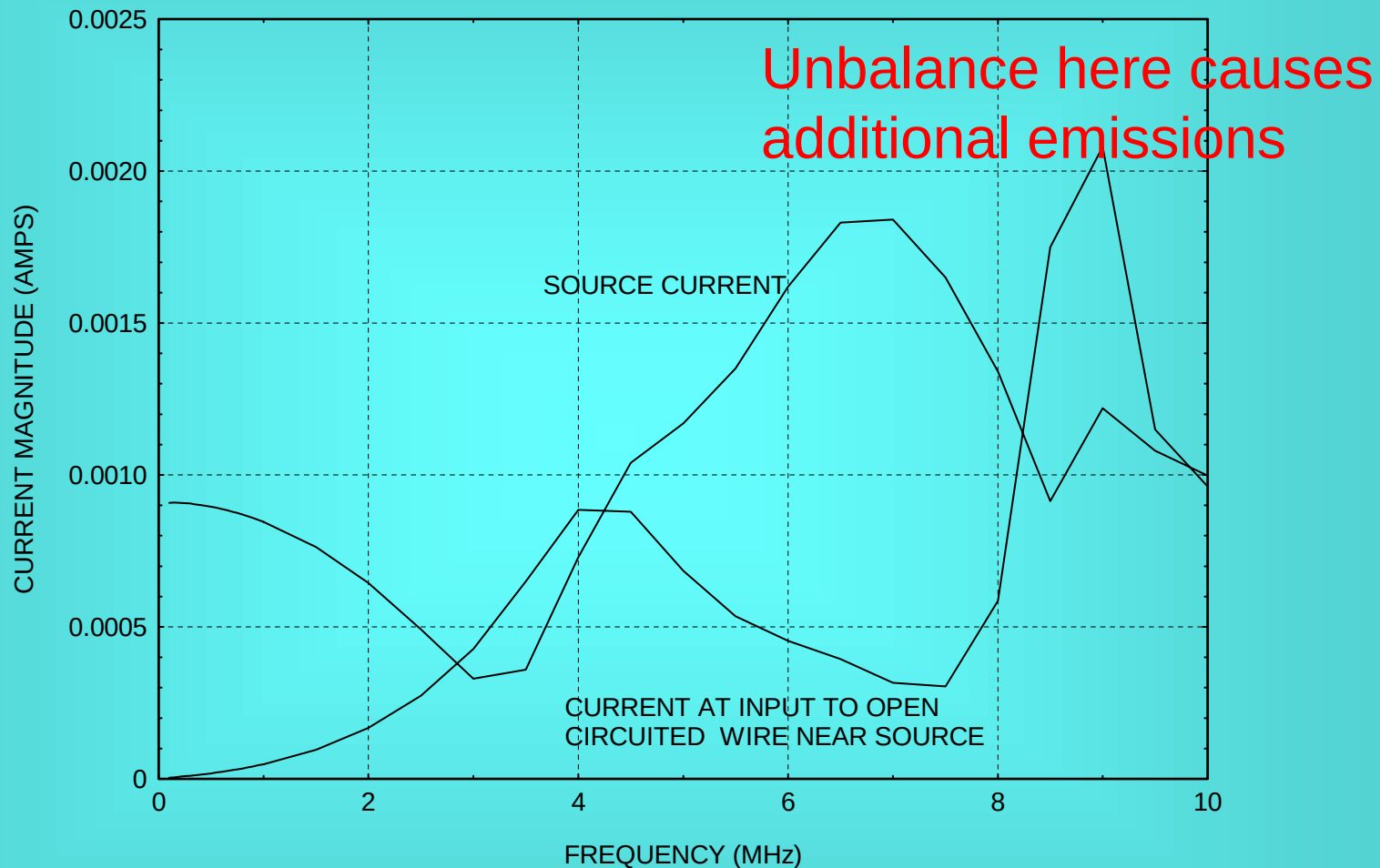


Low frequency source and wire currents



“Low” freq. - $I_w \approx 0$ as predicted by circuit theory

High frequency source and wire currents



“High” freq. - $I_w \neq 0$ – note $i_w > i_s$ at some frequencies

Technical challenge

- Can circuits be constructed that will allow communication signals to bypass these devices without attenuation? WiFi has been used to bypass distribution transformers
- Can the system be “conditioned” with these circuits without excessive cost? Ferrite devices have been used to provide more “balance” on power line circuits

Recent Experience with BPL

- Systems installed on overhead distribution lines with relatively few (i.e., fewer than roughly 1 per 100 m) installed connected devices have attenuation rates of approximately 30 dB/km.
- The maximum distance between repeaters for these same systems is approximately 600 m for a data rate of 10 Mbps.
- Underground distribution lines usually have 3x the attenuation rate but substantially less noise.

Note: This information is for systems that meet US FCC numerical emission standards

Regulations in the USA

Federal Communications Commission

Code of Federal Regulations

Title 47, Ch. I, Part 15, Subpart B – Unintentional Radiators

Radiated Emission Limits - Secs. 15.109,15.209

Measurement Frequency (MHz)	Field strength (microvolts/meter)	distance (meters)
0.009-0.490.....	2400/F(kHz)	300
0.490-1.705.....	24000/F(kHz)	30
1.705-30.0.....	30	30
30-88.....	100	3
88-216.....	150	3
216-960.....	200	3
Above 960.....	500	3

CISPR quasi-peak detector – 9 kHz bandwidth - loop antenna 19

Rights and responsibilities

Sec. 15.5

Persons operating...unintentional radiators...shall **not...have** any vested **right to continued use of any given frequency...**

Operation... subject to conditions that **no harmful interference is caused** and that **interference must be accepted.**

Harmful interference defined as:

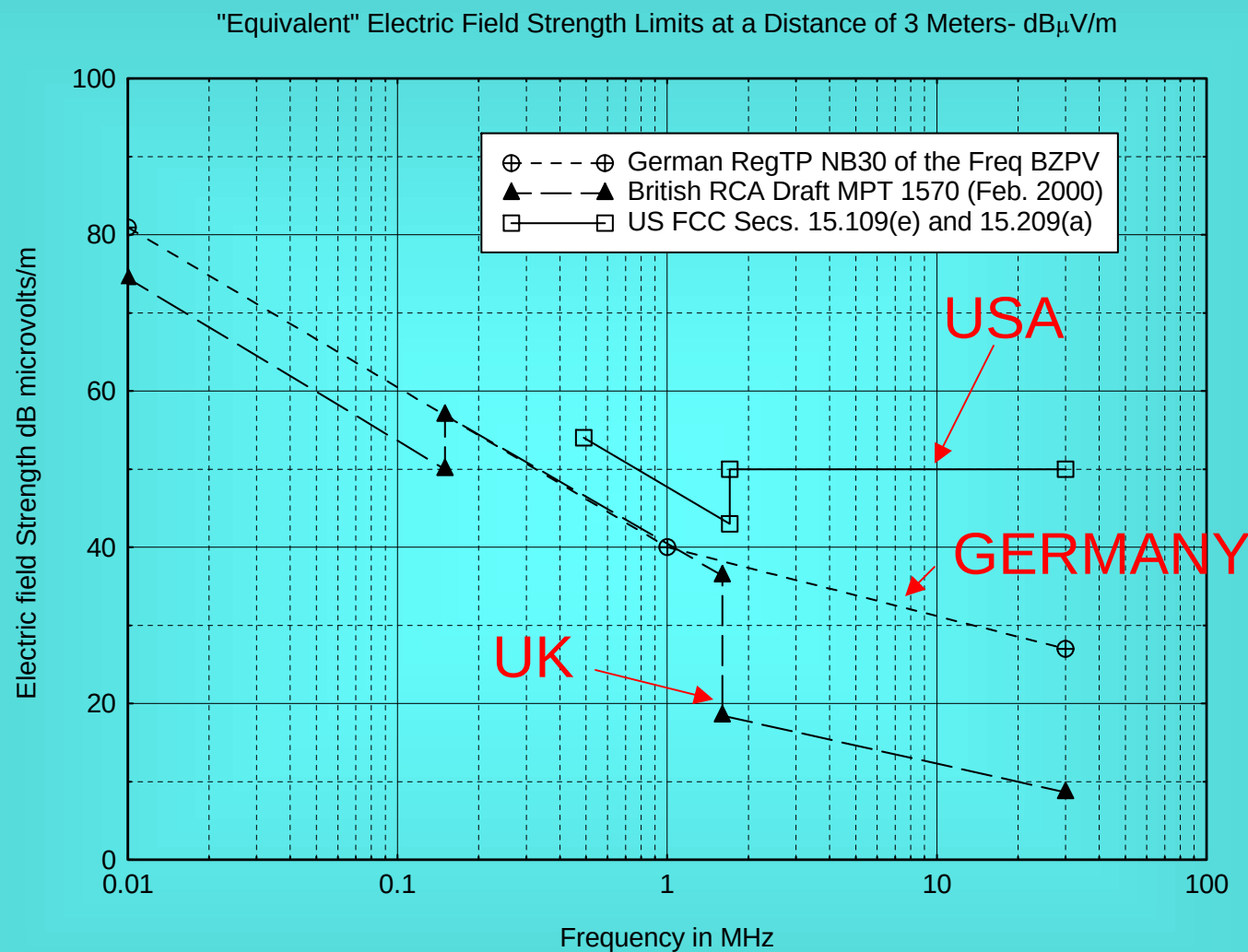
“any emission radiation or induction which endangers the functioning of a radio navigation service or other safety services or **seriously degrades, obstructs or repeatedly interrupts** a radio communication service operating in accordance with this chapter.”

Example of concern about interference

The American Radio Relay League (ARRL – an association of amateur radio operators) said,

“... Part 15 rules...(require that) devices not exceed specific emissions limits and that *they not cause harmful interference*. The maximum emissions limits are unacceptably high. The only reason Amateur Radio can live with those limits is because the rules ... require that the operators of Part 15 devices correct harmful interference. It is critical,... that the FCC be willing to enforce the non-interference clauses... The committee recommends that ARRL identify several cases of actual harmful interference that the Part-15 device operator is not willing to correct and that ARRL seek relief from the FCC in those cases.”

Comparison to European limits



The USA limits are more liberal by up to 20 dB (or more)

Recent Changes in FCC Regulations¹

October 2004

- Defines a BPL system
- BPL systems must incorporate adaptive interference mitigation techniques
- BPL systems must incorporate a remote controllable shut down feature in case harmful interference is being caused
- BPL may not use certain “excluded bands,” be located in certain “exclusion zones” or be used with coordination in certain “consultation areas” **Note: need only 20 dB filtering**
- BPL emissions testing must be performed “*in situ*” according to the following regulations.

¹ FCC Report and Order 04-245, October 28, 2004

Measurement Requirements (overhead)

- Normally at a distance of 10 meters from the power line
- Normally at distance along the line of 0, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and 1 wavelength from injection point based on mid-frequency band of EUT
- Testing must be repeated for each BPL component
- Distance corrections based on slant range distance

Reaction from the ARRL

- The ARRL claims that the required filtering is not sufficient to eliminate harmful interference
- They authorized filing of a “*Petition for Reconsideration*” to the FCC
- They authorized their general counsel to “prepare to pursue other available remedies as to procedural and substantive defects”