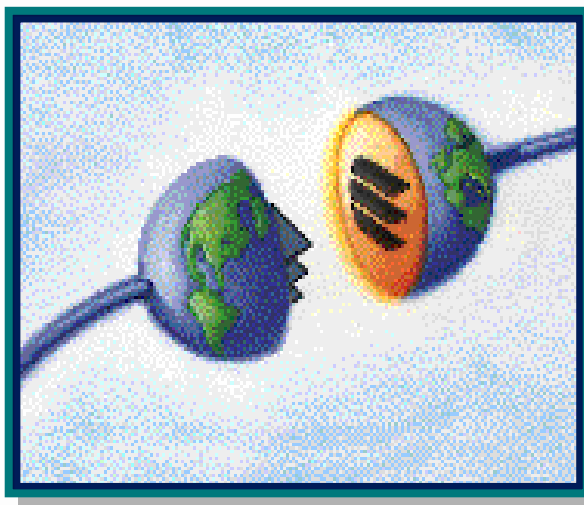


Power Line Communication Technology Update



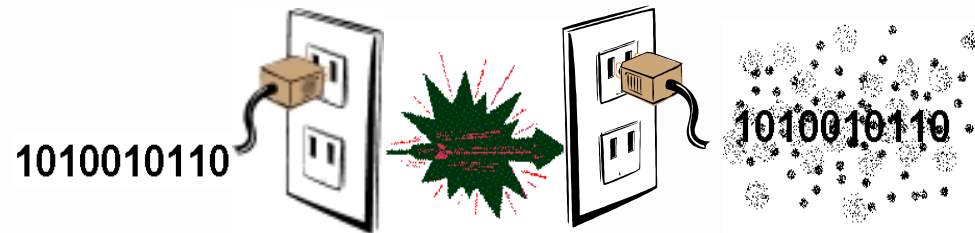
By Walter Downey and Phil Sutterlin

Echelon Corporation
415 Oakmead Parkway
Sunnyvale, CA 94086
1-888-ECHELON (888-324-3566)
www.echelon.com

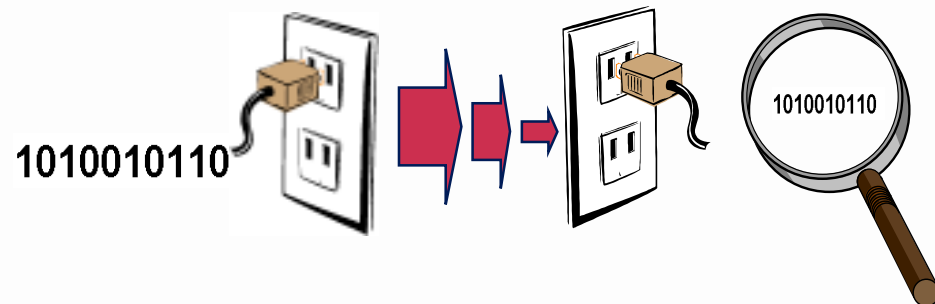
Power Line Communications

- ◆ Power lines are designed for delivering power not data

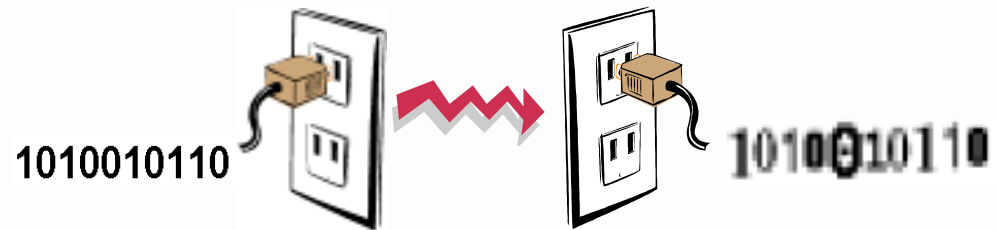
- ◆ High noise



- ◆ High attenuation

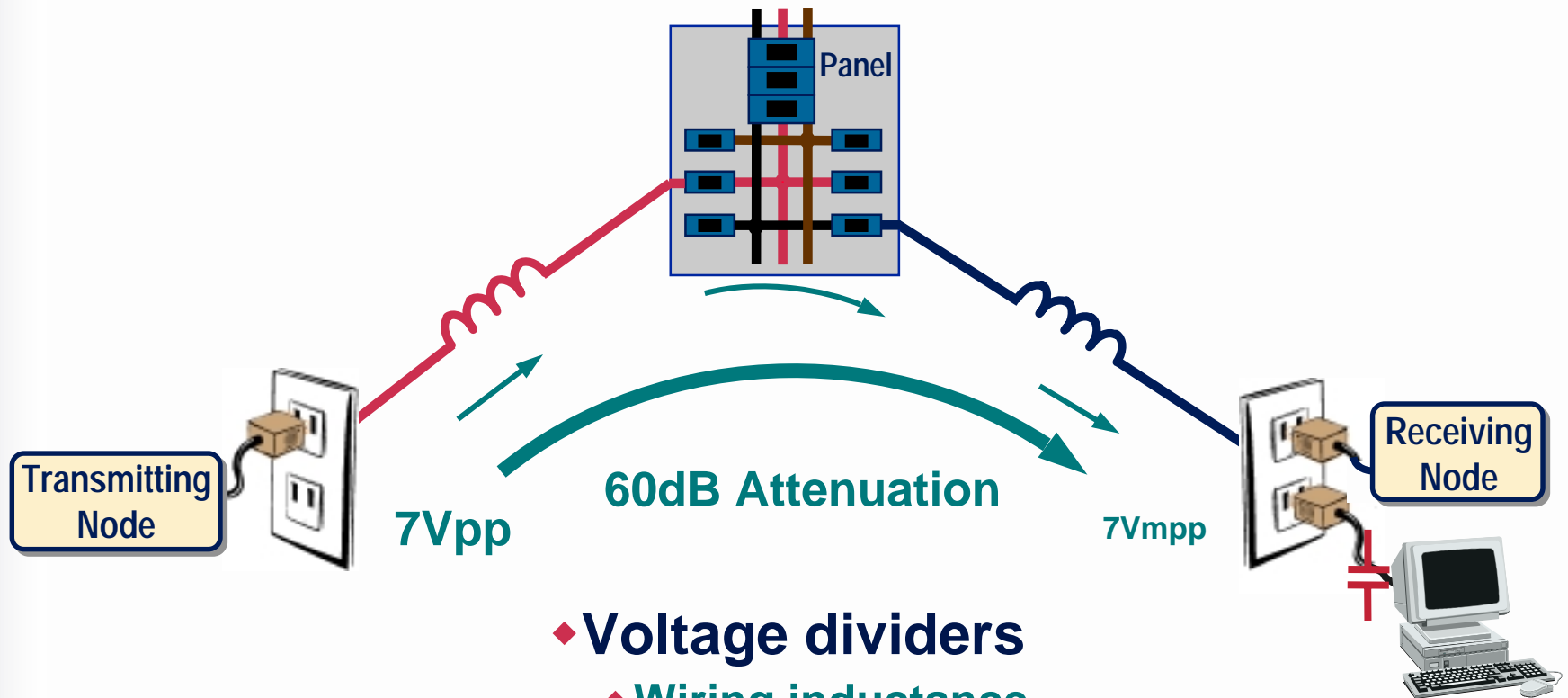


- ◆ Signal distortion



- ◆ It takes a sophisticated modem to communicate reliably

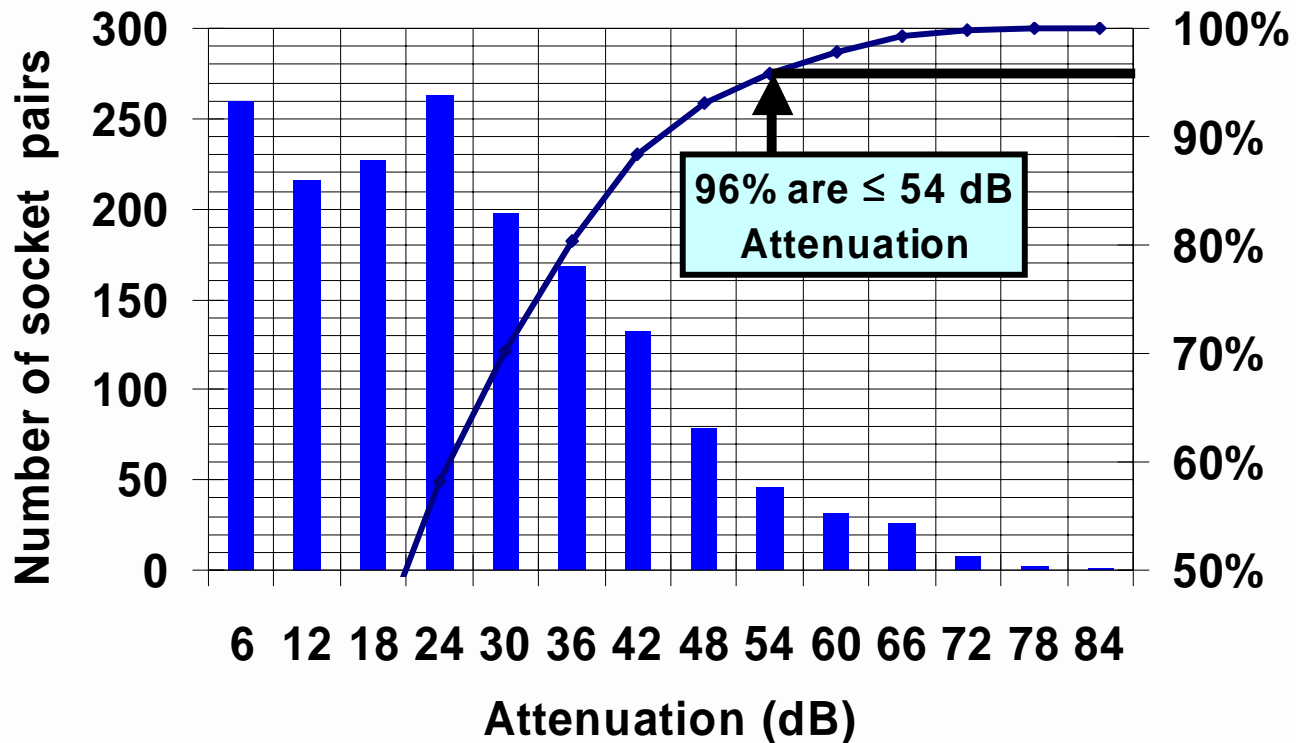
What Causes Attenuation ?



- ◆ Voltage dividers
 - ◆ Wiring inductance
 - ◆ Shunt loads
 - Panel loading
 - EMC capacitors
- ◆ Phase coupling loss

$$\text{Attenuation(dB)} = 20 * \text{LOG}_{10} \left(\frac{V_{\text{transmit}}}{V_{\text{receive}}} \right)$$

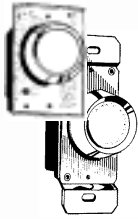
Power Line Attenuation in Homes



◆ World wide home attenuation results

- ◆ 1,889 randomly selected socket pairs
- ◆ 169 houses, apartments, condominiums
- ◆ 5 countries
- ◆ Data taken at 132 kHz

Noise Sources



- ◆ **Dimmers**

- ◆ Triac controlled lights
- ◆ Produce large impulses at 100Hz or 120Hz



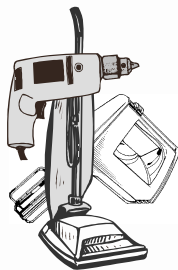
- ◆ **Switching power supplies**

- ◆ Fundamentals at 20kHz to >1MHz
- ◆ Rich in harmonics



- ◆ **Power line intercoms**

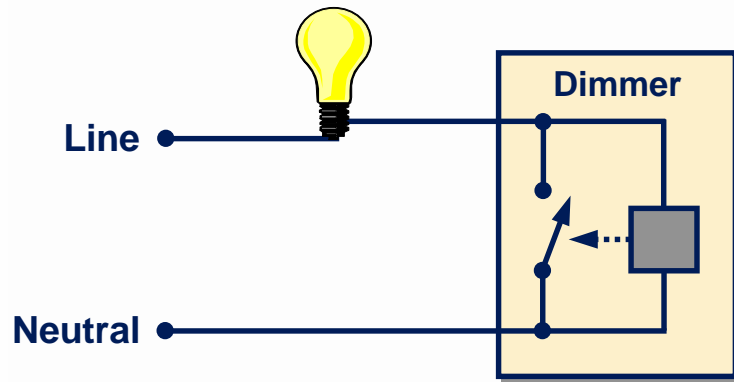
- ◆ $3V_{pp}$ to $7V_{pp}$ from 150kHz to 400kHz



- ◆ **Universal series wound motors**

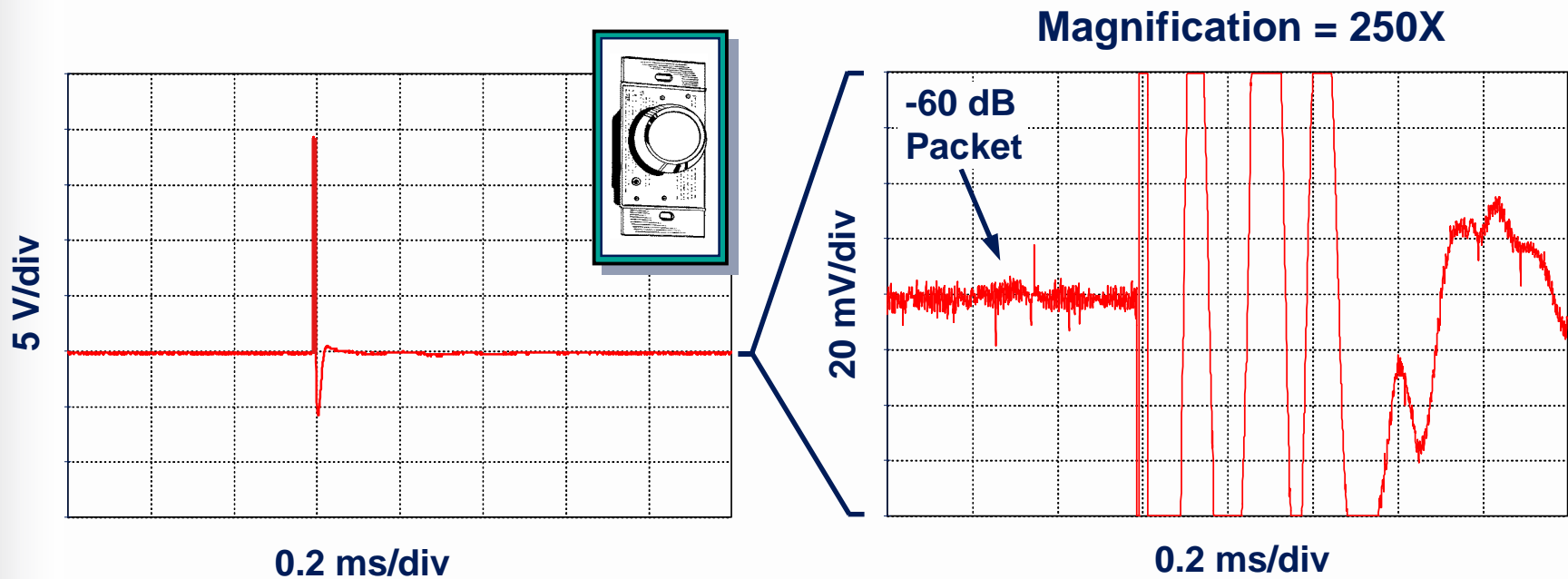
- ◆ Vacuum cleaners, kitchen appliances, drills
- ◆ High repetition rate impulses

Dimmer Noise

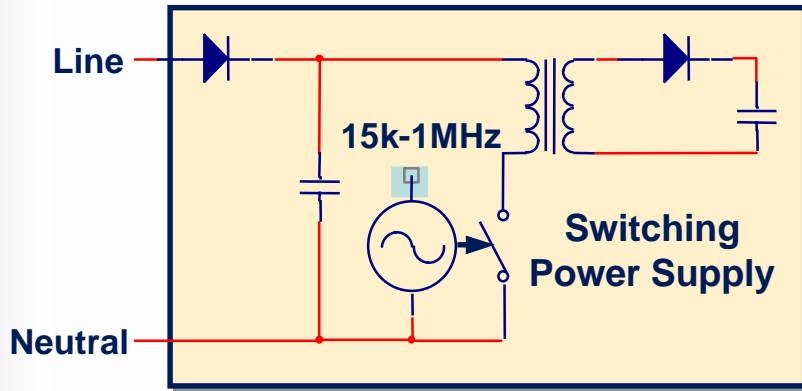


◆ Characteristics:

- ◆ Large 20V to 50 Volt impulses
- ◆ Repetition rate 100Hz or 120Hz
- ◆ Ringing tail ~150kHz

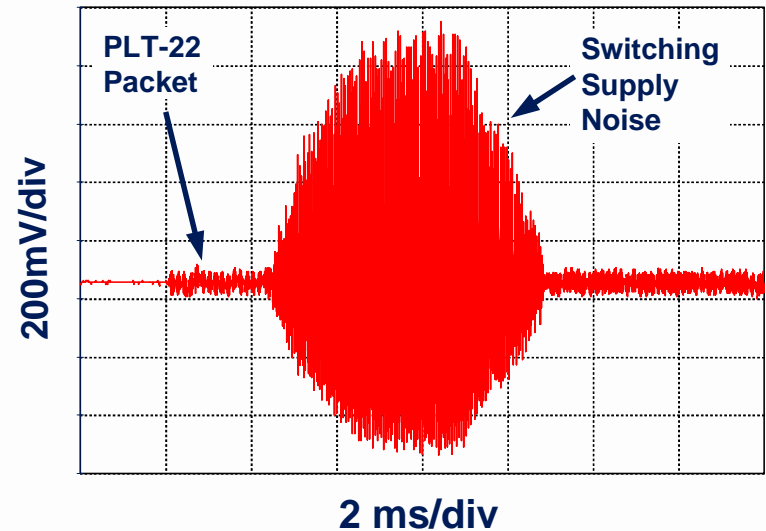
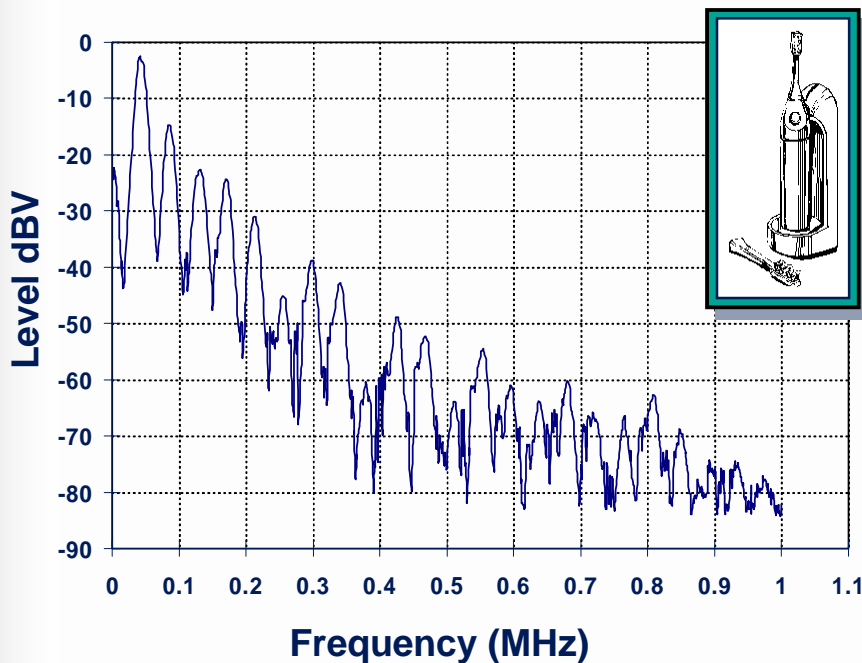


Switching Power Supply Noise

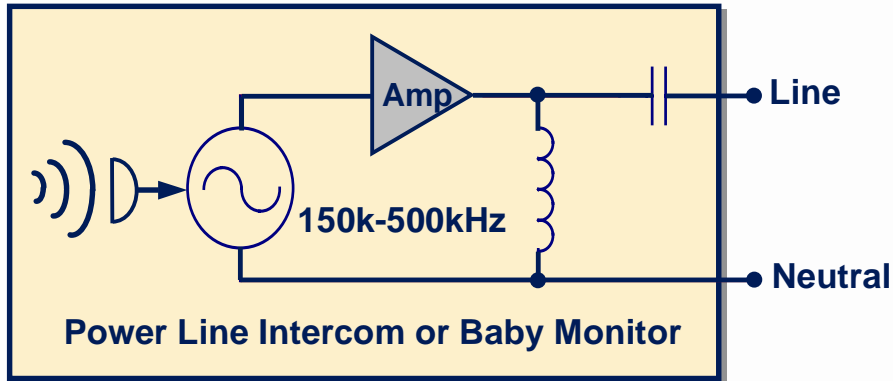


◆ Characteristics:

- ◆ Oscillator 20kHz to >1MHz
- ◆ Conducts oscillator noise onto power line
- ◆ Frequency often varies with load
- ◆ Harmonics can be large

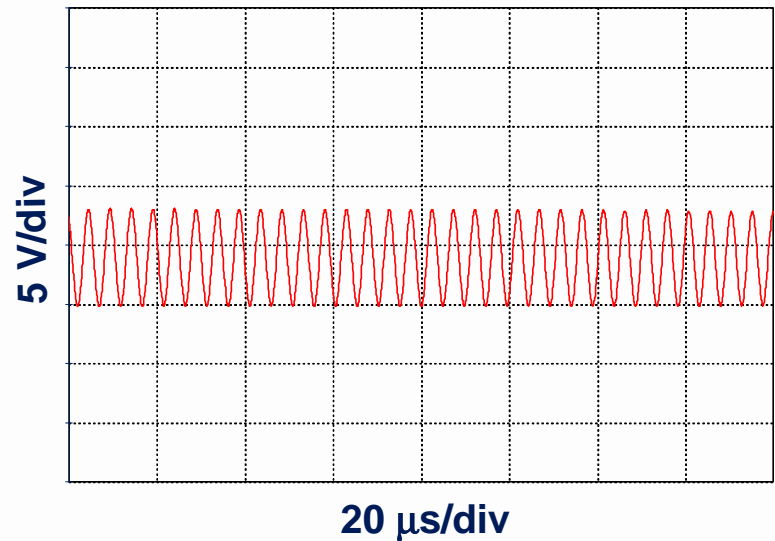
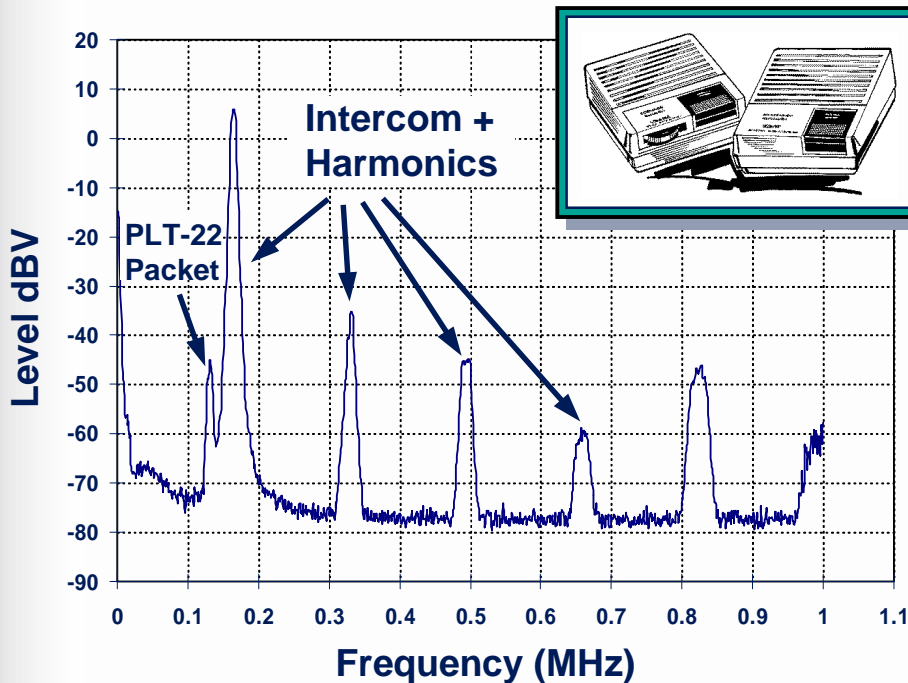


Intercom Noise

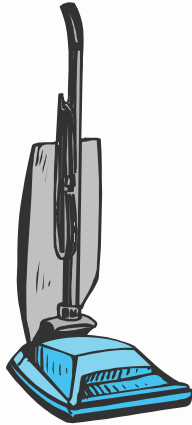


◆ Characteristics:

- ◆ ~ 30kHz bandwidth
- ◆ Typically 150kHz to 500kHz
- ◆ Output Level up to 7V_{pp}
- ◆ Harmonics can be large

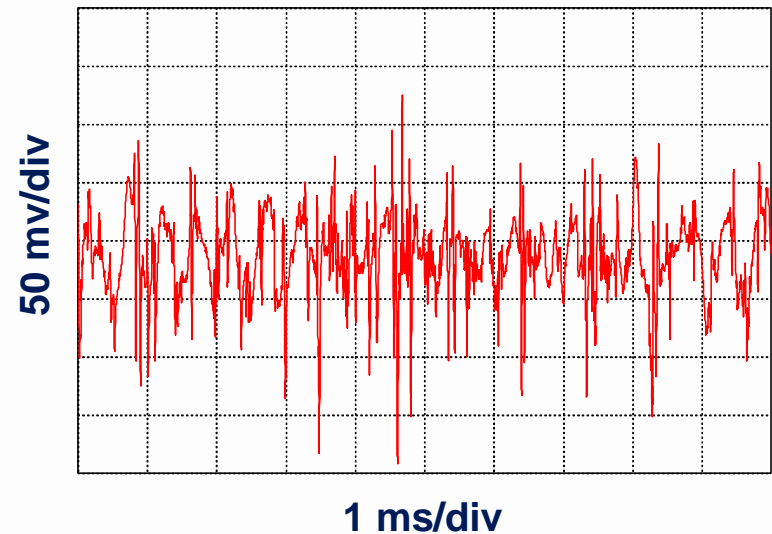
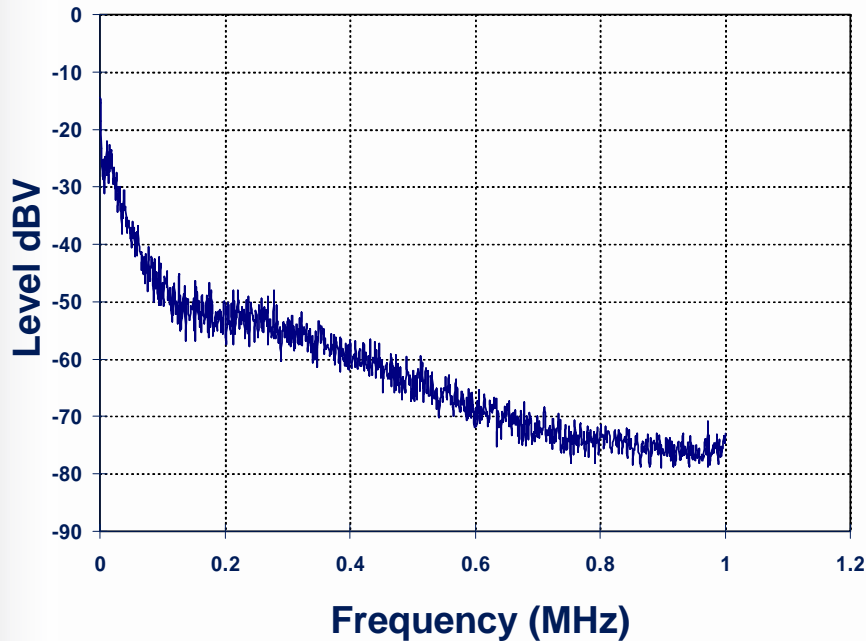


Universal Series Wound Motors

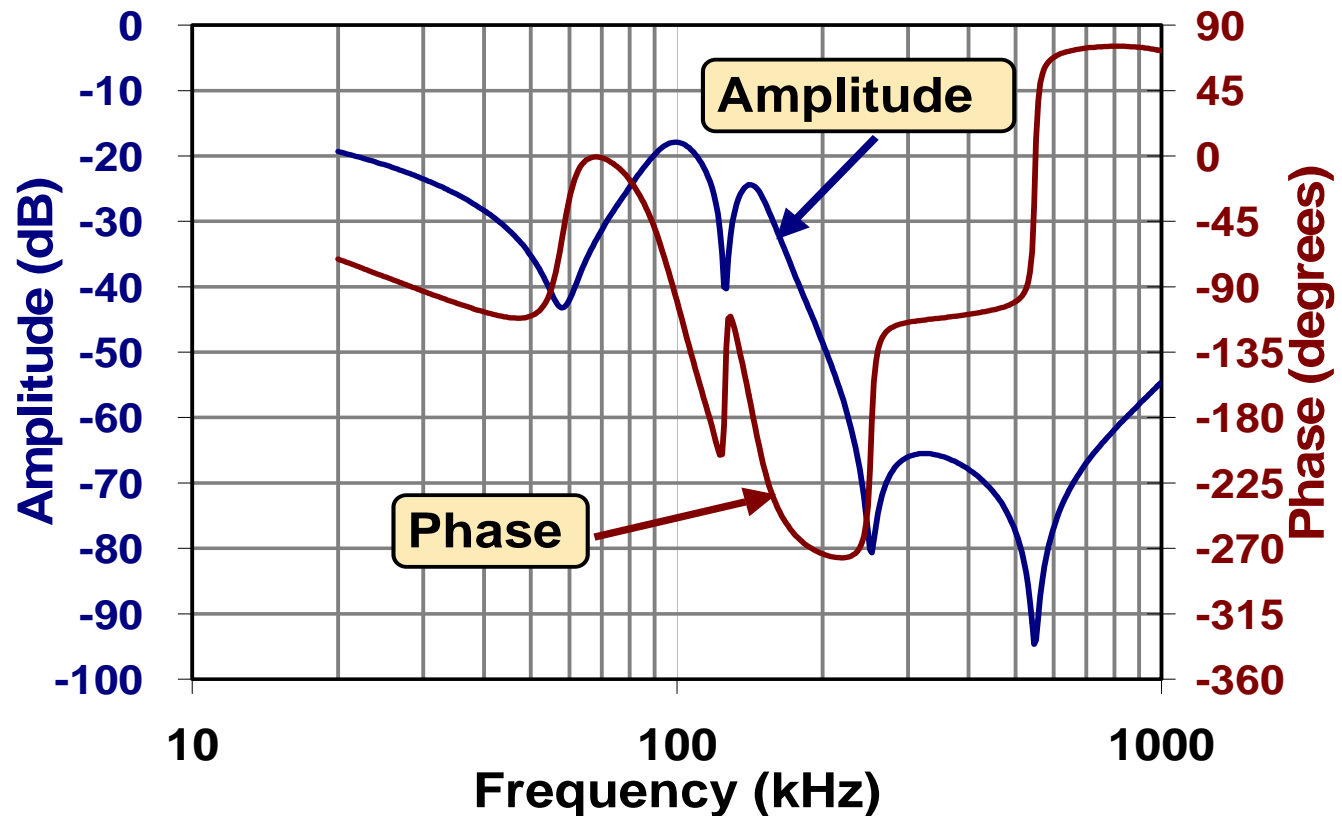


◆ Characteristics:

- ◆ Impulse noise
- ◆ Rep rate of few kilo-Hertz
- ◆ Wide band spectrum



Distortion



- ◆ Non-flat frequency response
- ◆ Non-linear phase response
- ◆ Time varying impedence

Communication Options

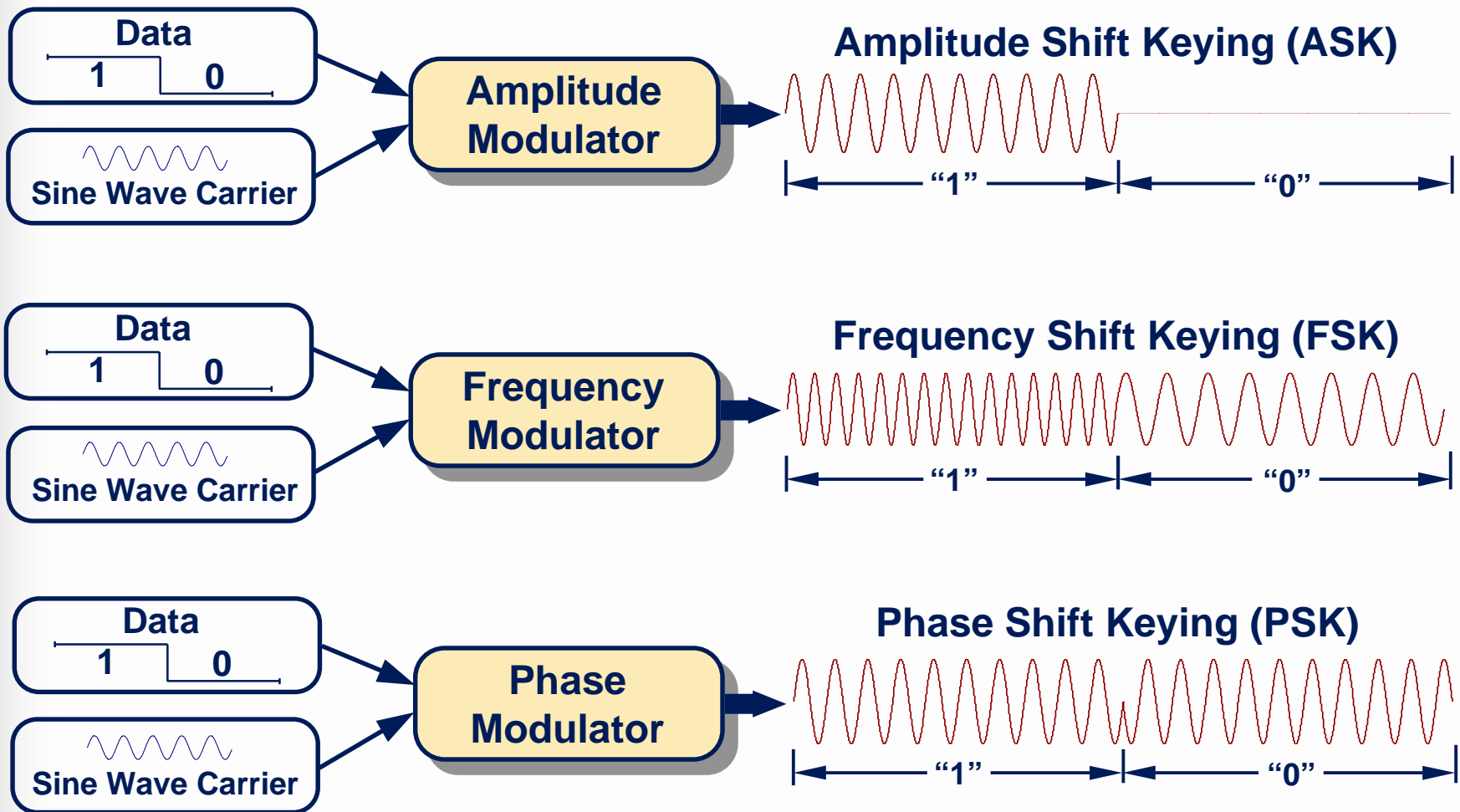


- ◆ **Phase Locked Loop - Based Narrow Band**
 - ◆ Amplitude Shift Keying
 - ◆ Frequency Shift Keying
 - ◆ Phase Shift Keying

- ◆ **Correlator - Based Spread Spectrum**
 - ◆ Direct Sequence
 - ◆ Chirp
 - ◆ Frequency Hop

- ◆ **Digital Signal Processing - Based BPSK**
 - ◆ Dual Carrier Frequency Operation
 - ◆ Impulse Noise Cancellation
 - ◆ Adaptive Distortion Correction

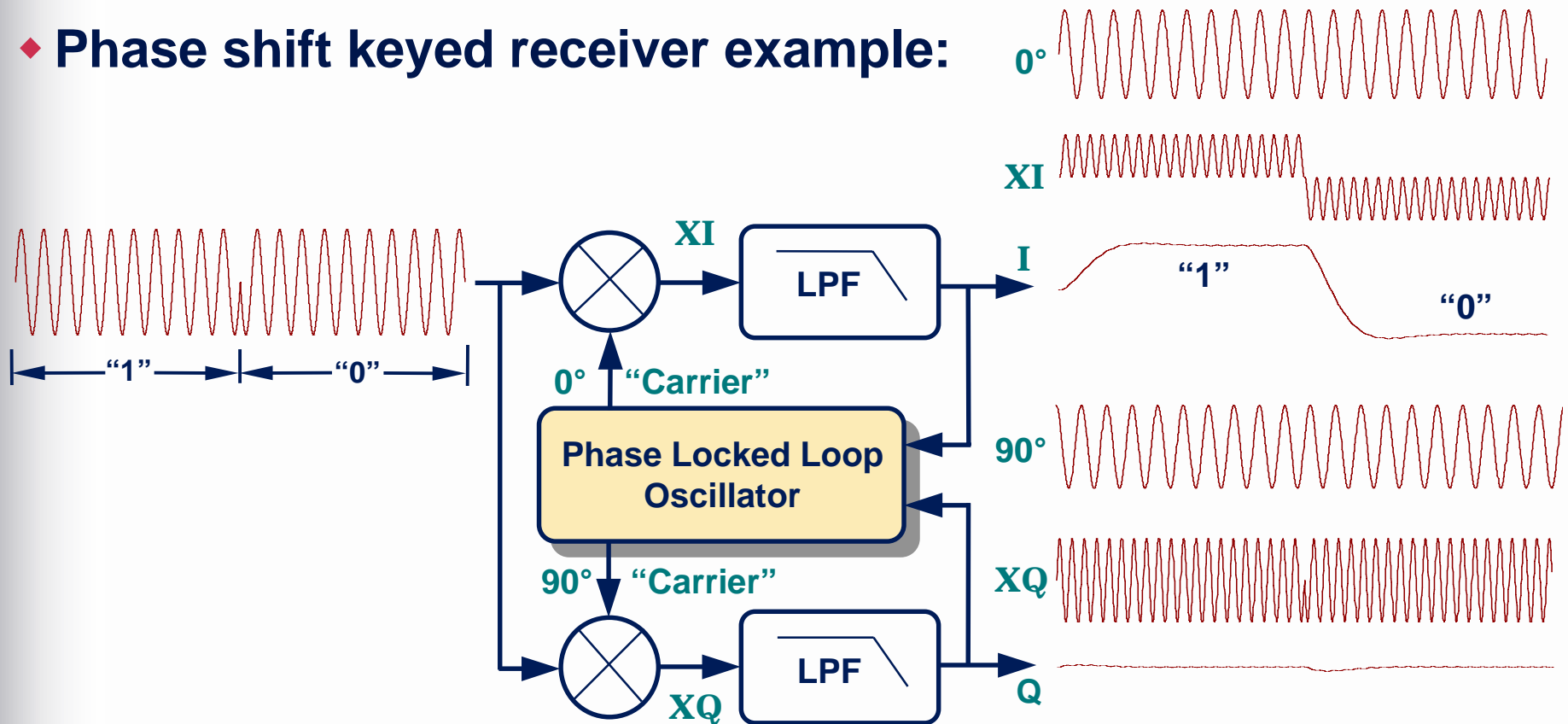
Narrow Band Transmission



- ◆ In practice the waveforms are shaped to contain their spectra

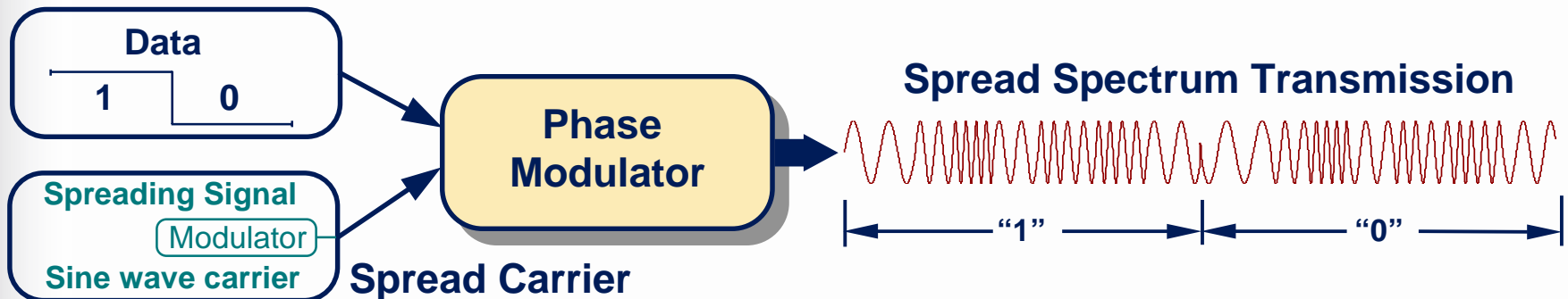
PLL Based Narrow Band Reception

◆ Phase shift keyed receiver example:



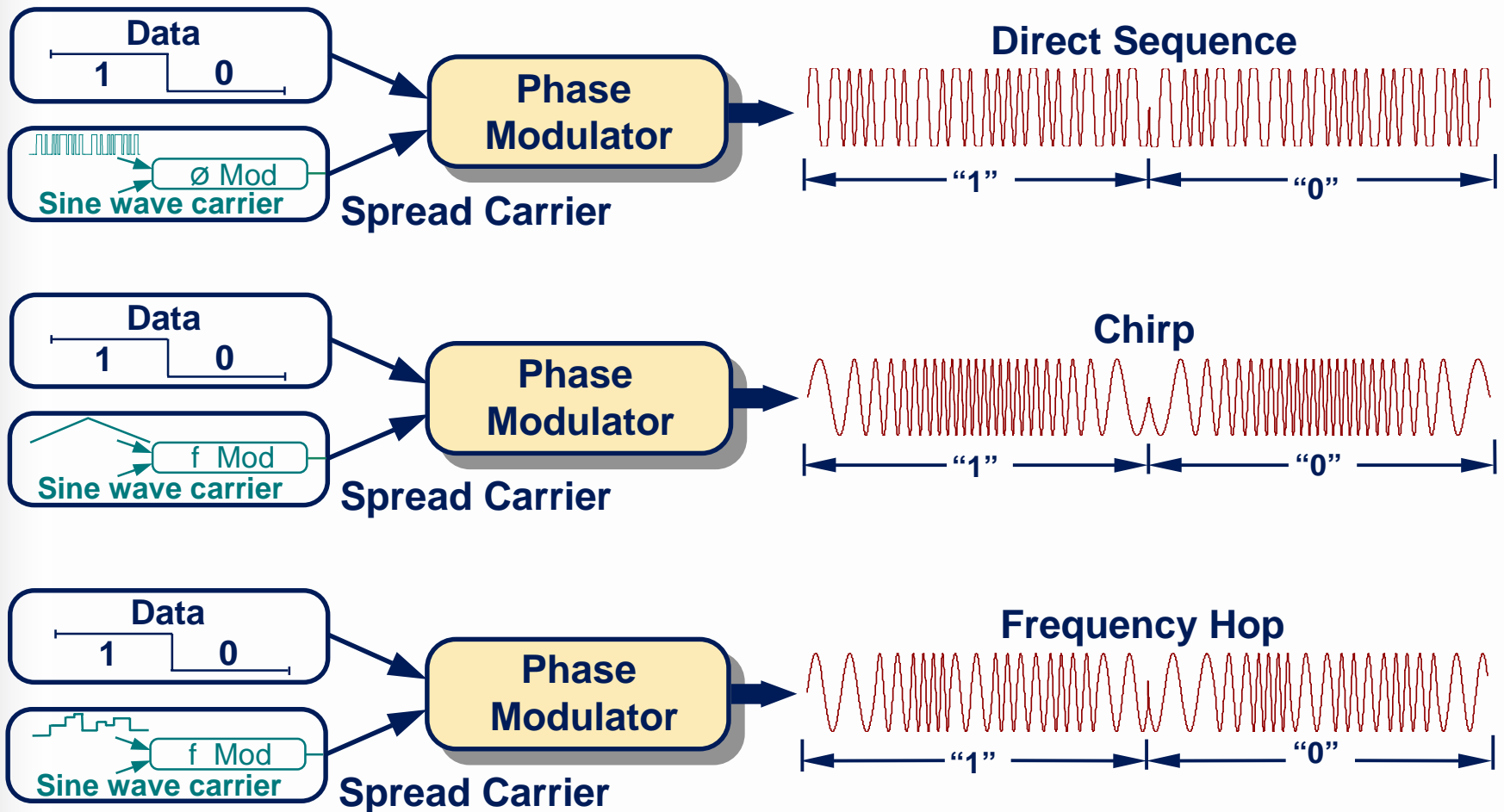
What is Spread Spectrum ?

- ◆ A method of transmission where:
 - ◆ The transmitted signal occupies a bandwidth considerably greater than the minimum necessary to send the information and ...
 - ◆ Some function other than the information being sent is employed to determine the resulting modulated bandwidth.



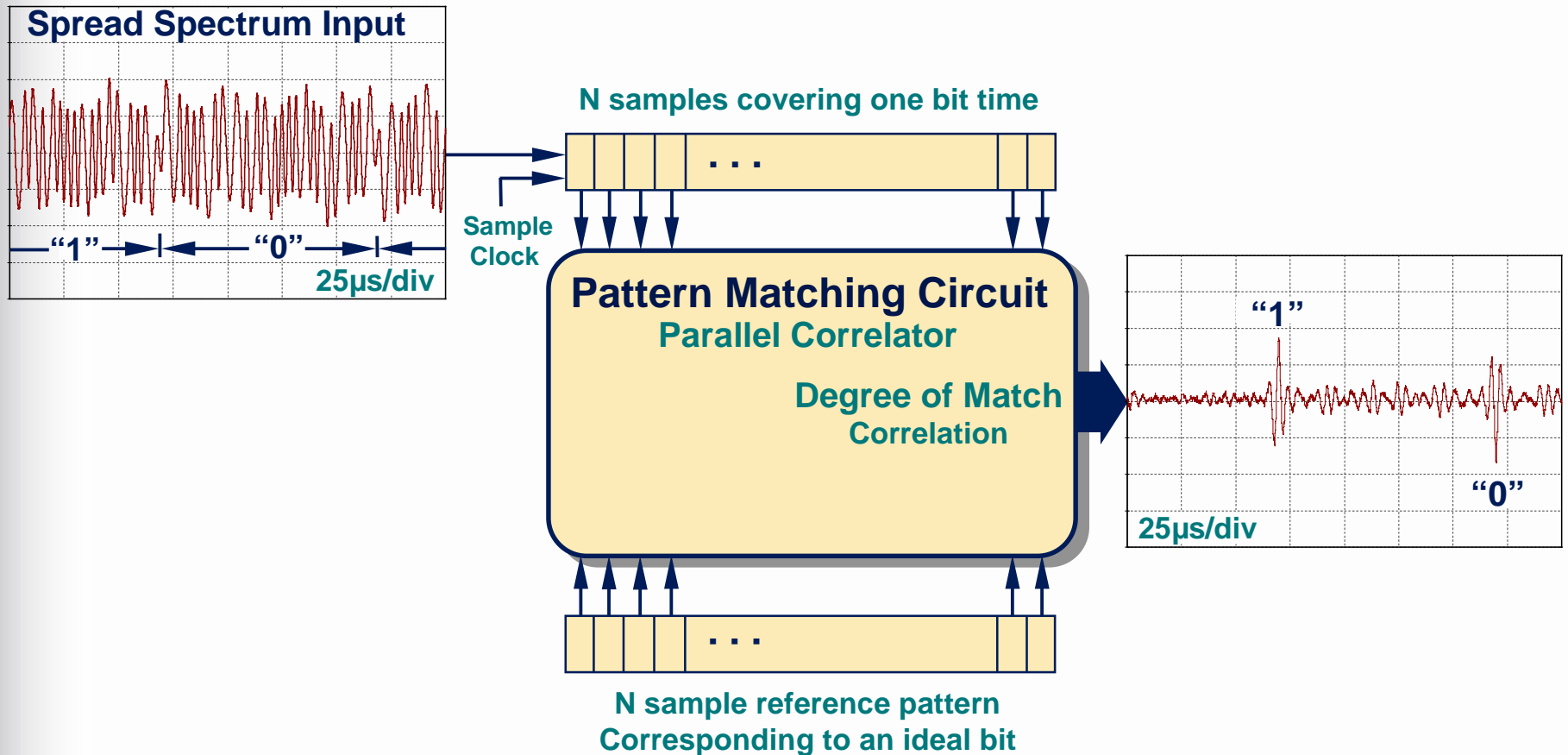
- ◆ In practice, a pre-spread carrier waveform may be stored in ROM

Spread Spectrum Transmission



◆ In practice, the waveforms are shaped to control their spectra

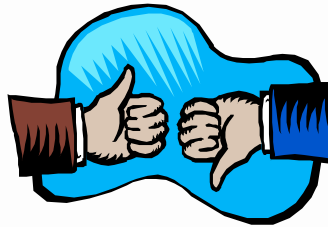
Spread Spectrum Reception



- ◆ To contain cost the spread spectrum input is digitized to a single bit in amplitude

What Does Spread Spectrum Do ?

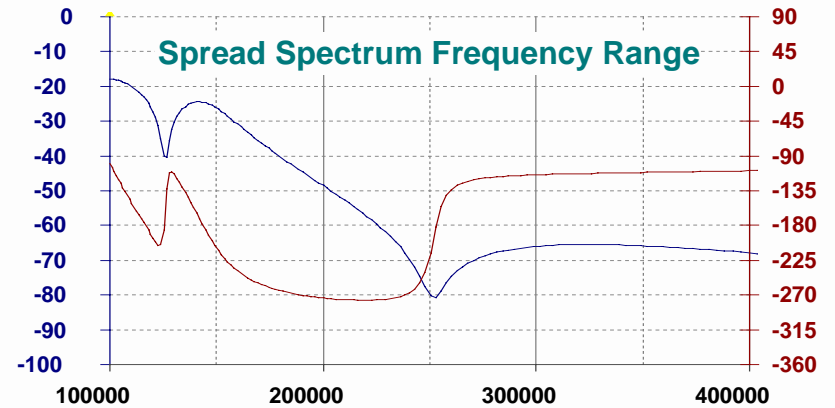
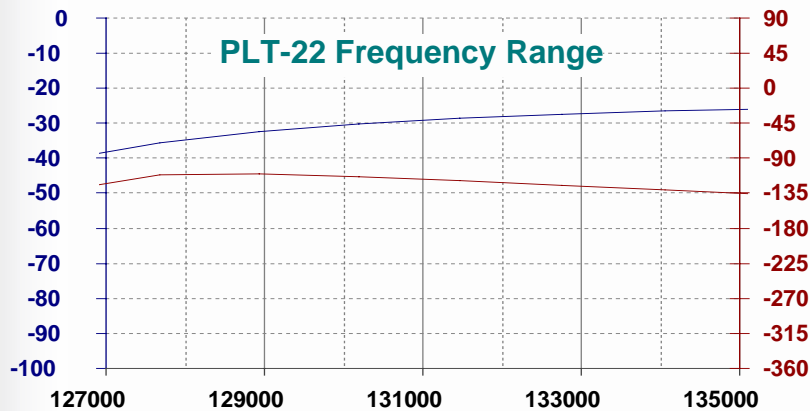
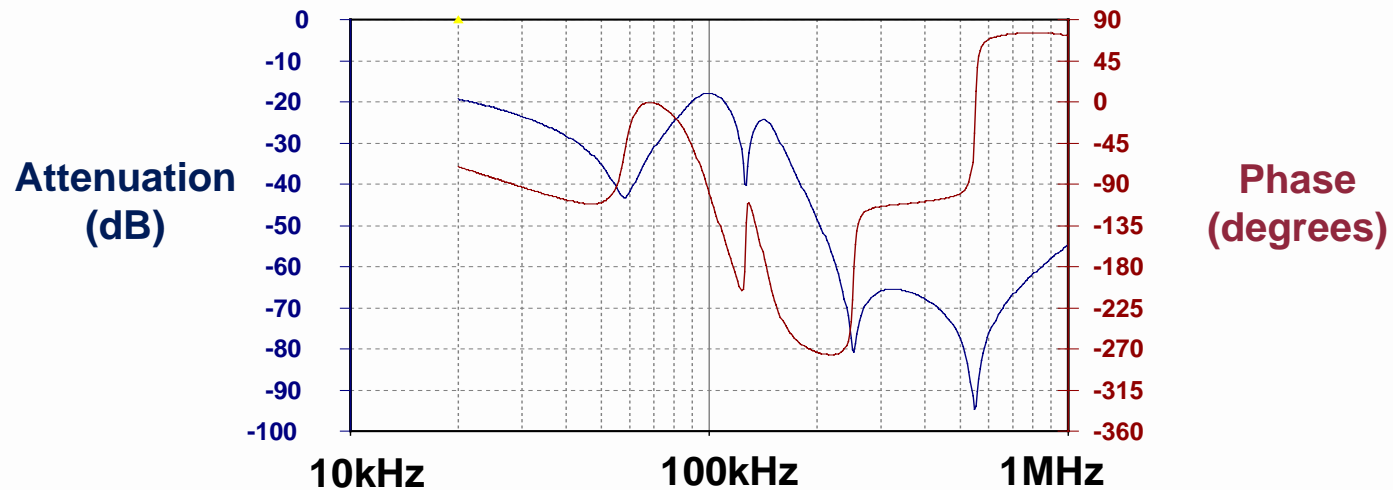
- ◆ **Aids performance with medium level tones and impulses**
 - ◆ The maximum improvement set by the degree of spreading (process gain)
 - ◆ The process gain of a 10kbps, 100kHz-400kHz signal is 15dB ($10 \cdot \log 30$)
 - ◆ In practice, this gain is only a few dB



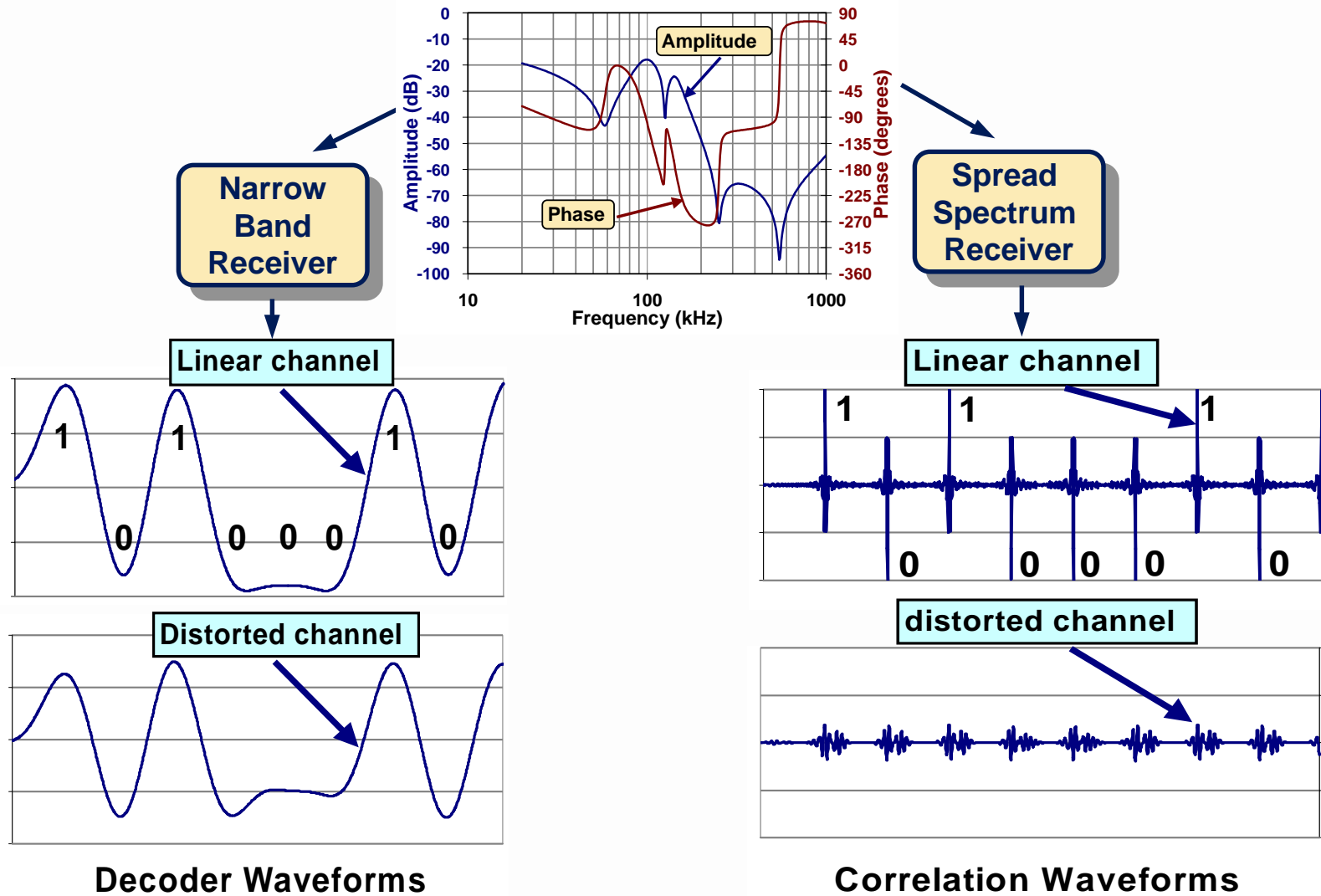
- ◆ **Increases susceptibility to signal distortion**
 - ◆ Requires distortion correction
 - ◆ Not recommended for residential applications
 - TV sets are the most common source of distortion
- ◆ **Degrades tonal noise rejection**
 - ◆ Wider receive bandwidth picks up more large amplitude interference

Distortion Characteristics

- ◆ Narrow band signals are subject to much lower levels of distortion than wide band spread spectrum signals

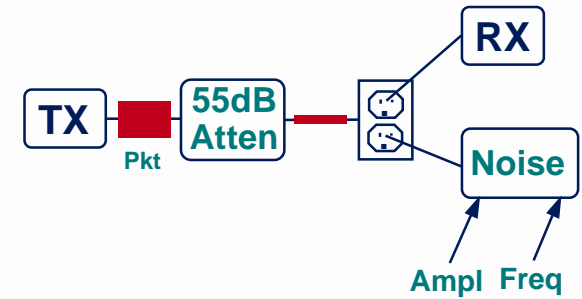


Distortion Consequences

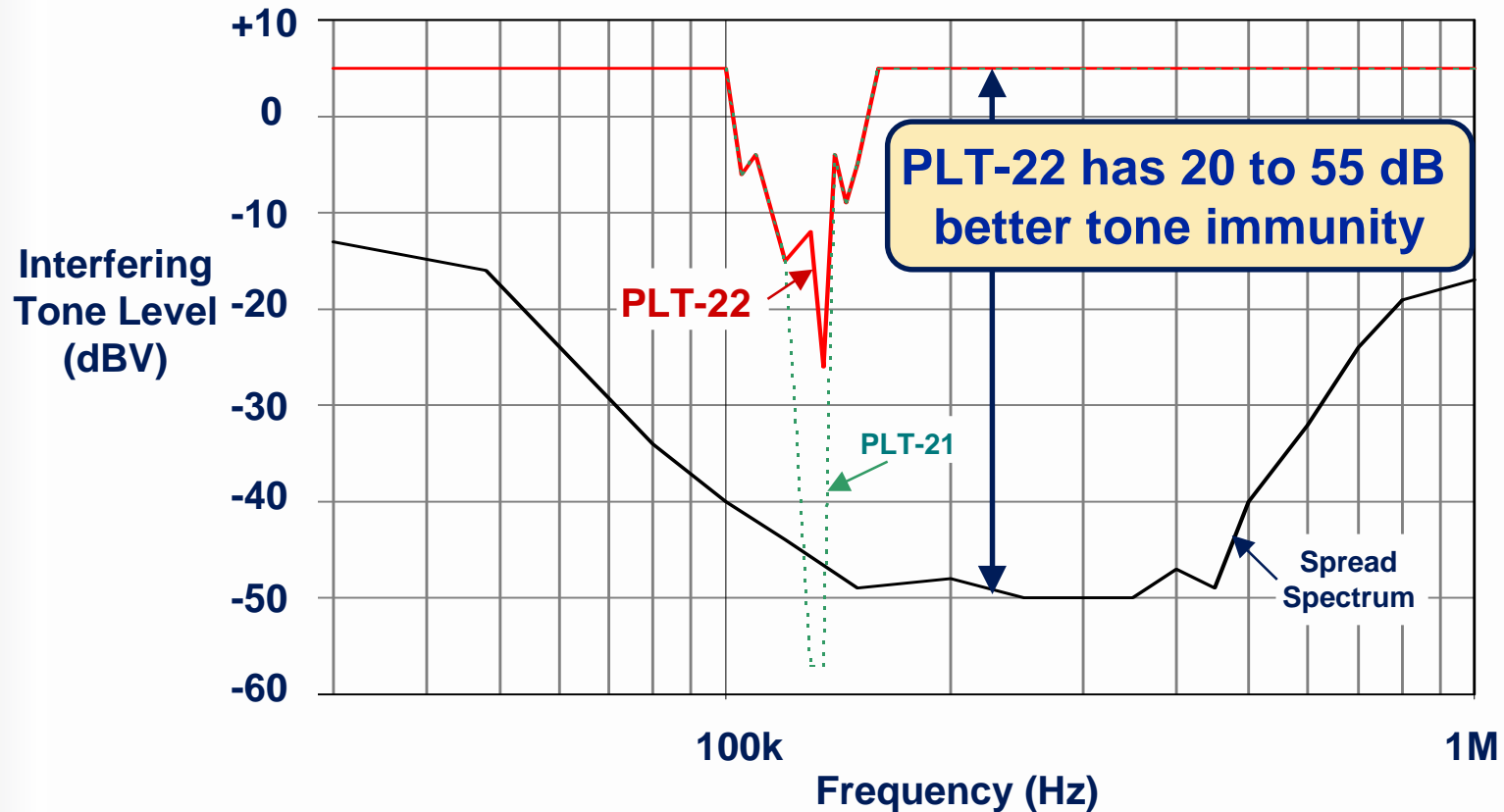


- ◆ Spread spectrum requires much more correction

Tone Immunity

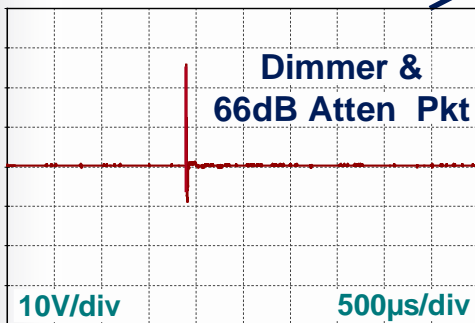
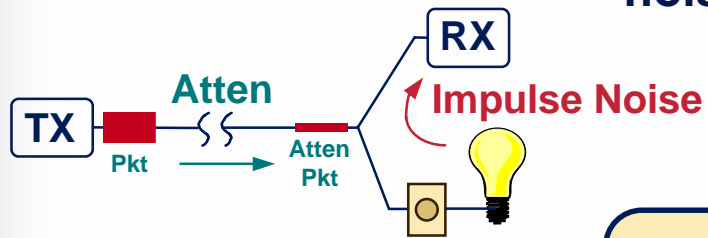


- ◆ Level of interfering tone which can be tolerated while receiving a 55dB attenuated packets

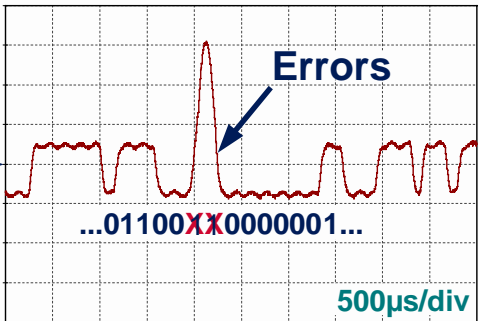


Impulse Noise Cancellation

- ◆ Digital Signal Processing can overcome impulse noise limitations of narrow band systems

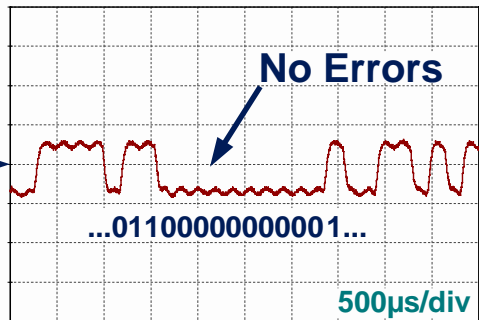


Conventional PLL based
Narrow Band Receiver



DSP Receiver with:

- ◆ Dual Carrier Operation
- ◆ Impulse Noise Canceler
- ◆ Distortion Correction



Which Technology is Best to Use ?

**Spread
Spectrum**

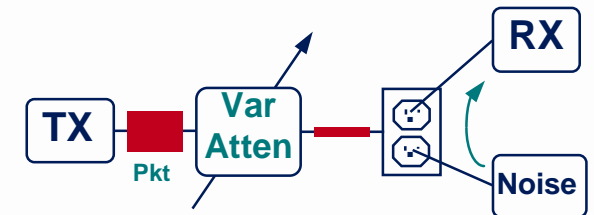


**Dual Frequency
Narrow Band**

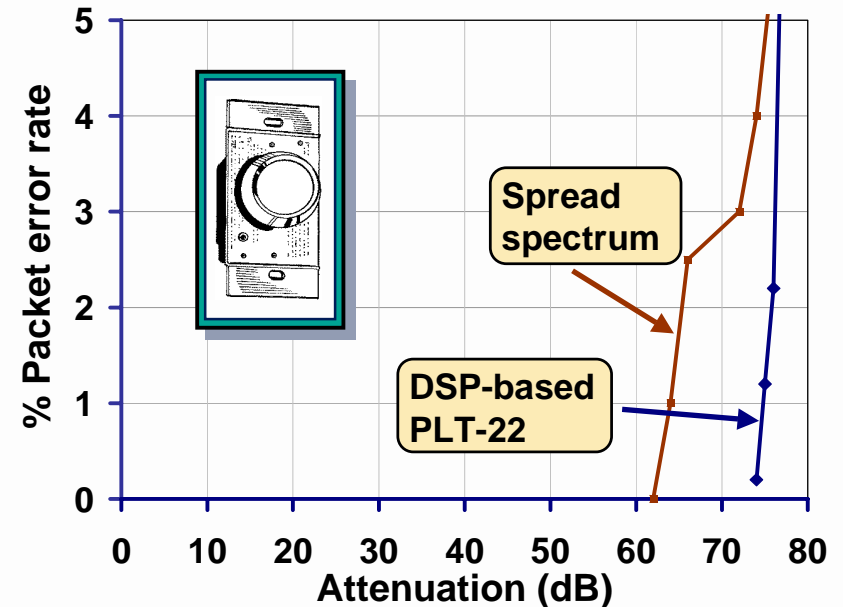
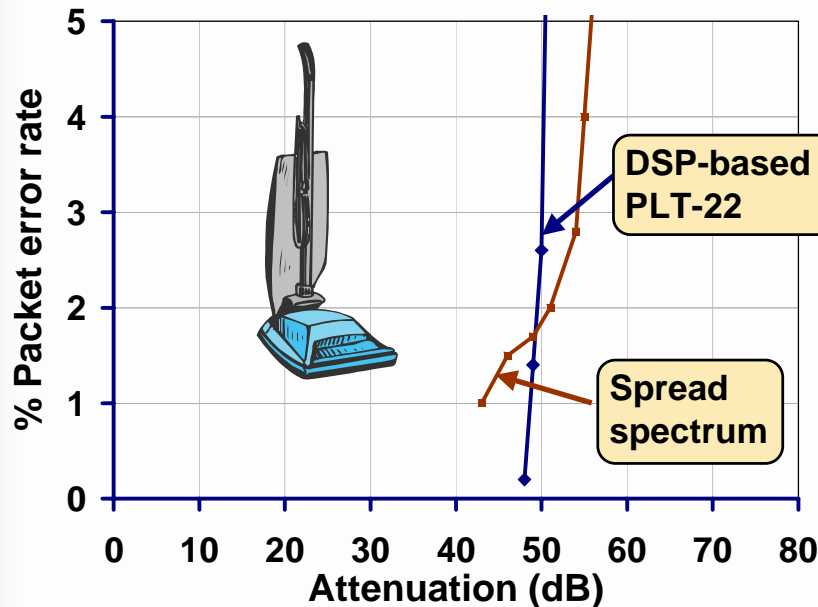
**Motor and Dimmer noise sources
Switching power supplies and Intercoms
TVs and other distortion sources
Regulatory considerations**

- ◆ **Echelon is uniquely qualified to answer this question**
Echelon is the only company to have fielded both

Dimmers and Motors

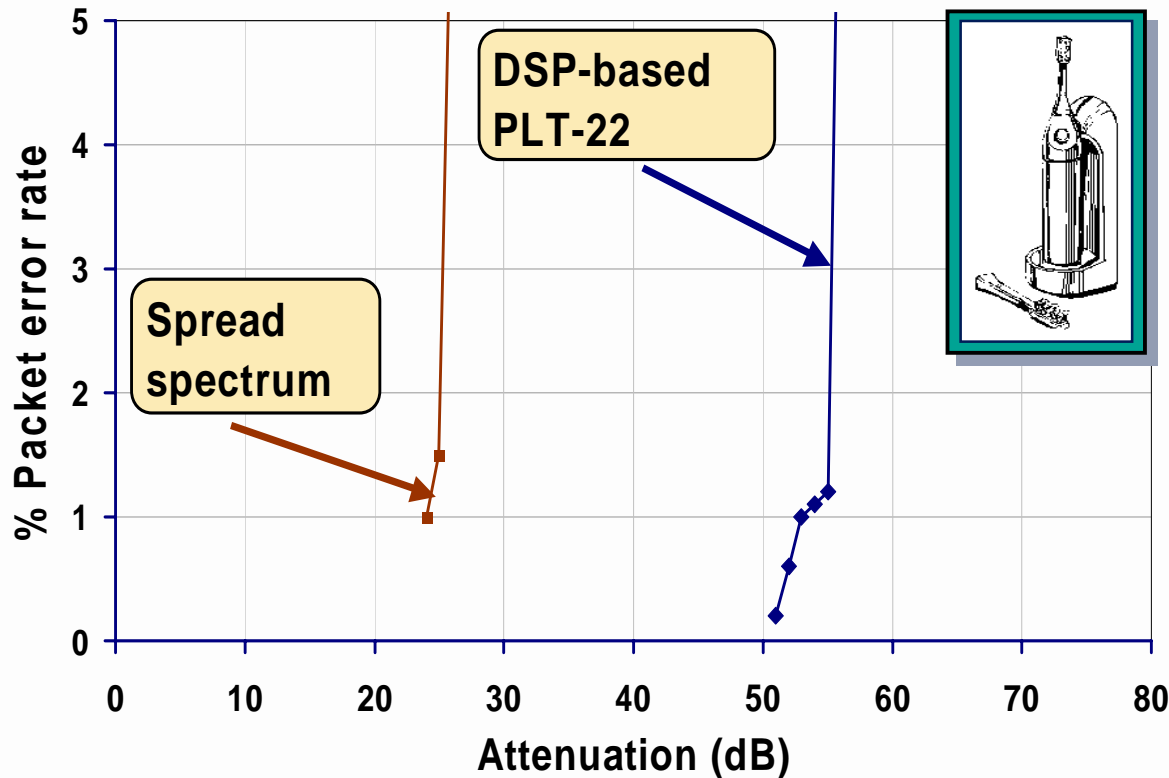
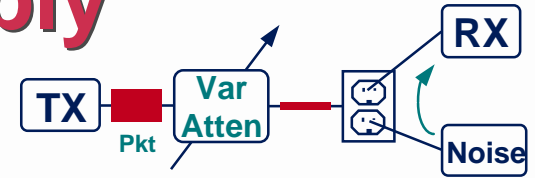


Attenuation Tolerance



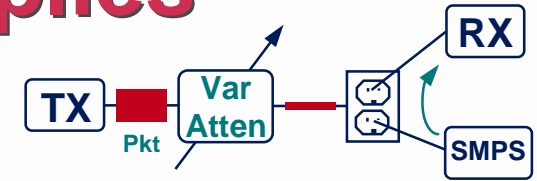
- ◆ Either technology works well in the presence of light dimmers and motor noise
- ◆ Other impairments must be considered when comparing these two technologies

Switch Mode Power Supply



- ◆ Spread Spectrum has problems with tonal noise
- ◆ The dual carrier PLT-22 performs far better
 - ◆ Even though a harmonic of this SMPS is directly in the PLT-22's primary carrier frequency range

Switch Mode Power Supplies



Attenuation Tolerance (The higher the number the better)

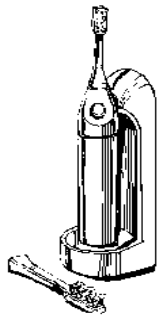


- ◆ Compact Fluorescent Lights - 2 randomly selected units

Spread spectrum	PLT-22
34dB	64dB
43dB	69dB

- ◆ Electronic Halogen Lights - 2 representative samples

Spread spectrum	PLT-22
10dB	52dB
17dB	57dB

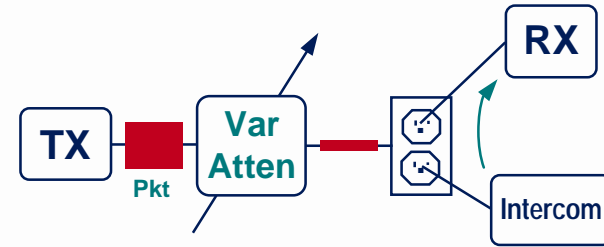


- ◆ Electric Toothbrush - A leading brand unit

Spread spectrum	PLT-22
20dB	56dB

- ◆ Spread Spectrum has problems with tonal noise
- ◆ The dual carrier PLT-22 performs far better

Power line Intercoms and Baby Monitors

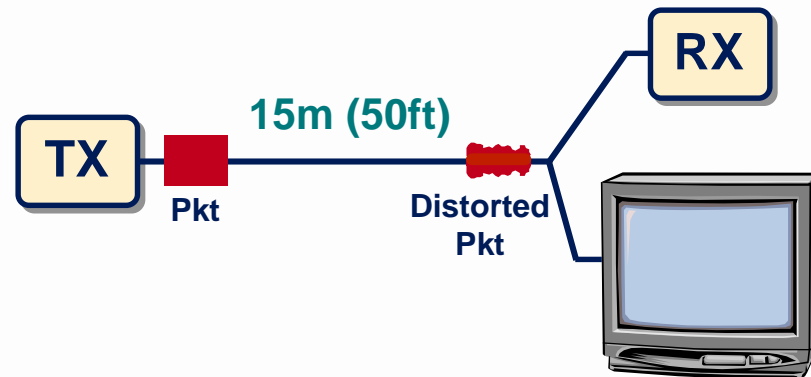


- ◆ Tolerable attenuation between transceivers

Intercom	DSP Based PLT-22	Spread Spectrum	“Enhanced Spread Spectrum
Realistic 43-218B	52dB	8dB	7dB
Command WI-3S	58dB	6dB	5dB
Radio Shack 43-207C	55dB	6dB	6dB
ComTalk GEE-825	53dB	9dB	10dB

Performance with TV Sets

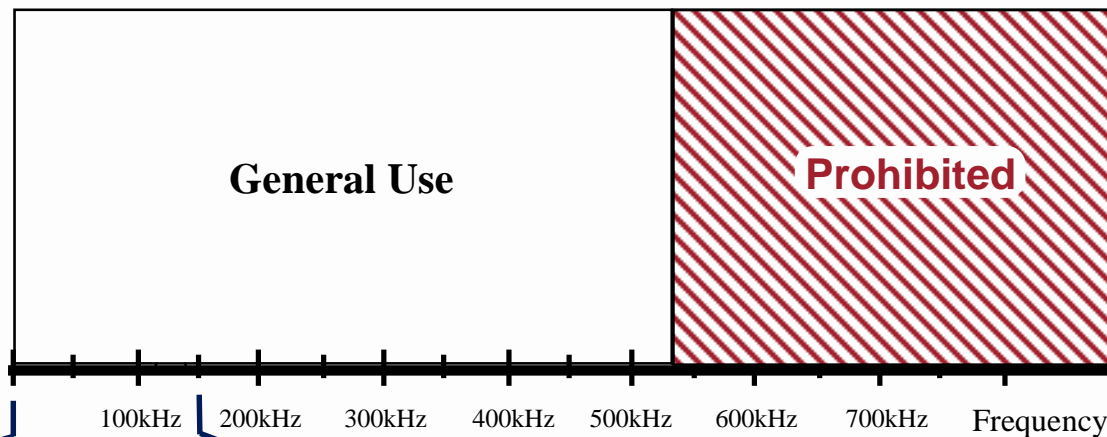
- ◆ 28 randomly selected TV's were tested:
(14 different brands with screen sizes from 13" to 35")



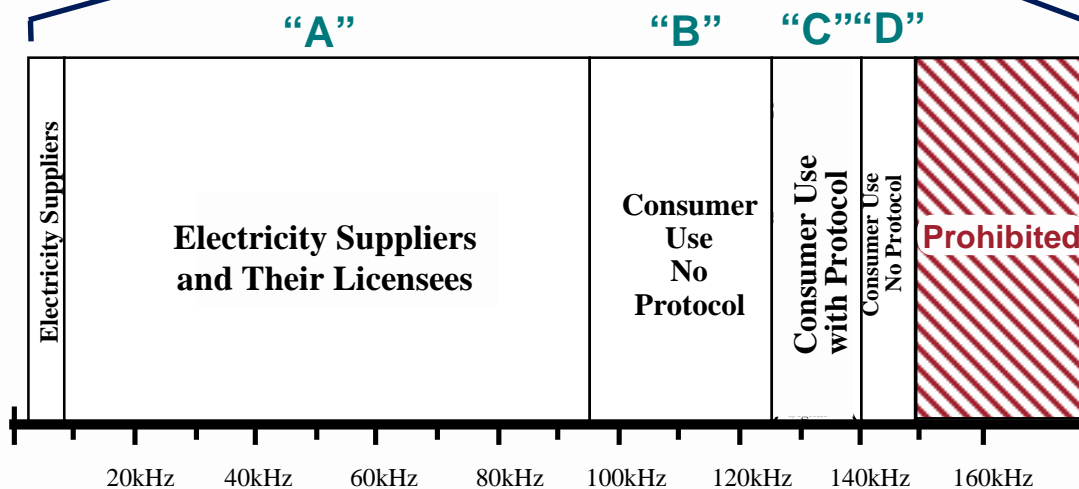
- ◆ Spread spectrum transceivers were unreliable with 1/4 of the TVs
(>25% physical layer packet error rate with 1 of every 4 TVs)
- ◆ The DSP based PLT-21/22 worked reliably with all 28 of the TVs
(<1% physical layer packet error rate with each TV)

Regulatory Considerations

◆ North American Regulations:



Band Designations



◆ CENELEC Regulations (Europe) :

Performance Summary

- ◆ Which technology is best?



Motor and Dimmer noise sources

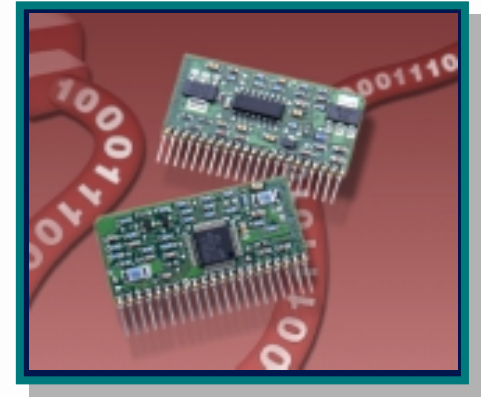
Switching power supplies and Intercoms

TVs and other distortion sources

Regulatory considerations

- ◆ The Dual Frequency PLT-22 has superior performance

The PLT-22 Transceiver



◆ World-wide operation

- ◆ Meets CENELEC, FCC, Industry Canada and Japan MPT regulations
- ◆ EIA 709.2 compliant

◆ Advanced Technology

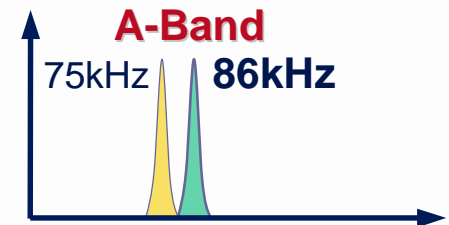
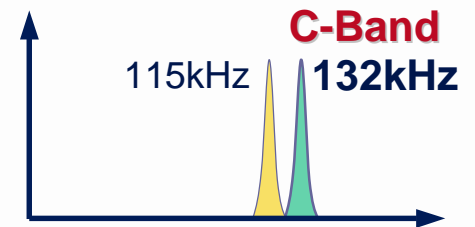
- ◆ Dual carrier frequency operation
- ◆ Digital signal processing

◆ Backward-compatible with the PLT-21

- ◆ Communicates with the PLT-20 and PLT-21
- ◆ Pin-compatible PLT-21 replacement

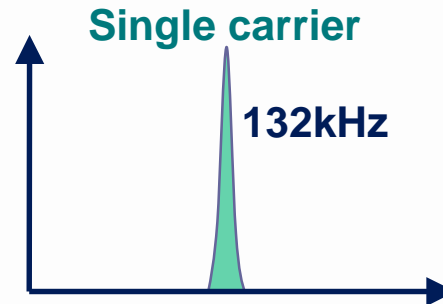
◆ European utility support

- ◆ Dual frequency DSP performance in the A-Band
- ◆ New A-band channel
 - Does not communicate with PLT-30

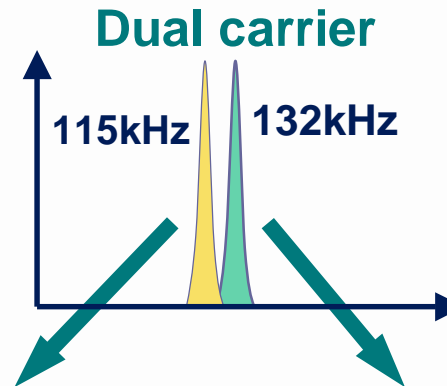


Dual Carrier Frequency Mode

PLT-20
and
PLT-21



PLT-22



- ◆ Alternate frequency used when 132kHz is blocked
 - ◆ More error correction than 132kHz
- ◆ Improved 132kHz performance
 - ◆ Better distortion correction
 - ◆ Better discrimination between packets and noise

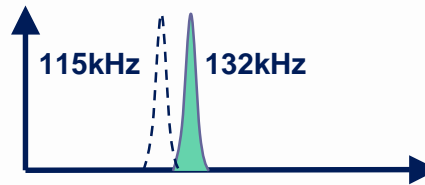
Use with 1999 STDXCVR.TYP file to activate dual carrier mode

Backward Compatible Operation

- ◆ Backward compatible with the PLT-20 and PLT-21

Acknowledged service

1st and 2nd try



3rd and 4th try

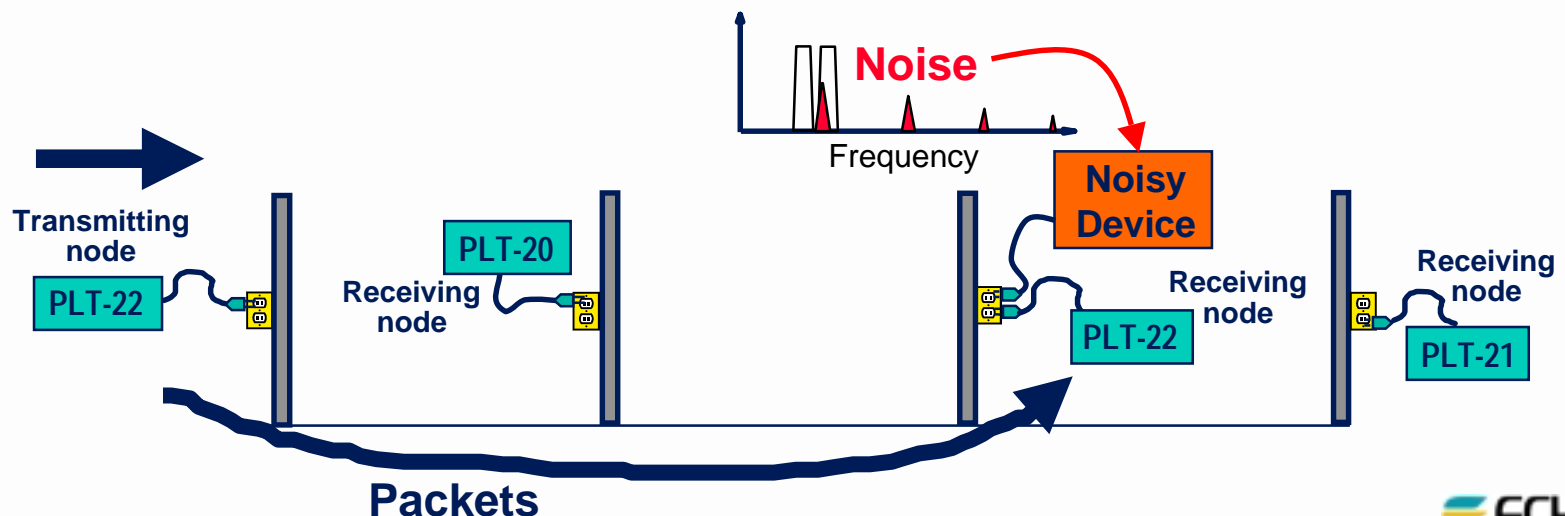


Unacked repeat service

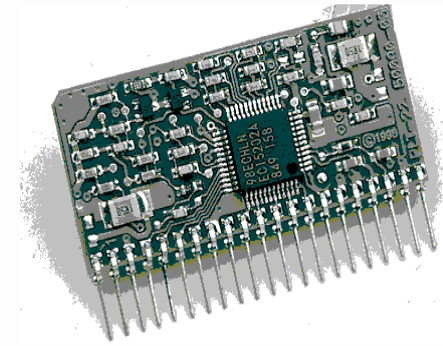
1st and 3rd packet

2nd and 4th repeat

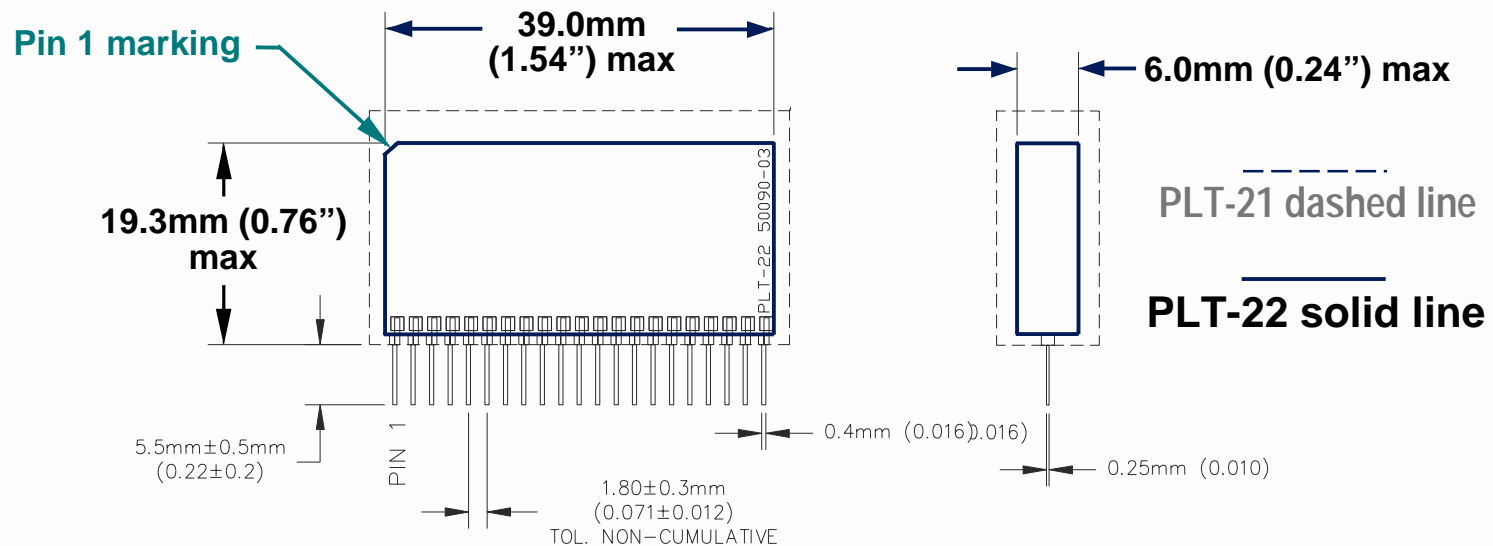
- ◆ Works even when primary frequency is jammed



PLT-22 Pin Compatibility



- ◆ Pin compatible with the PLT-21
 - ◆ Same pin functions
 - ◆ Same pin spacing
- ◆ Smaller outer dimensions than PLT-21
 - ◆ Supplied as an *un-coated* SIP



Be sure the PLT-22 does not contact other conductive components

PLT-22 Power Line Technology



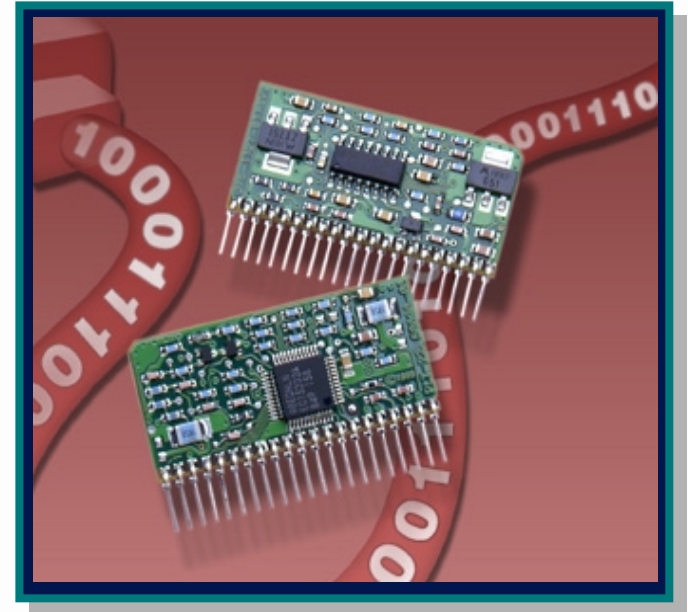
Superior Performance



Backward Compatible



Low Price



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Bringing the Internet to Life™