Powerline Communications Cross-phase Coupling

1. Introduction

Perhaps the most frequently asked question, regarding the viability of Intellon Homeplug Powerline Communications (PLC) home networks, is whether the poly-phase power to a dwelling is a hindrance to whole-house coverage. Is a Homeplug PLC signal on one phase blocked from crossing over to the other phase? Is it necessary to add some kind of coupling between phases?

The answer to these questions is no. The separate AC phases used to supply AC power throughout a dwelling offer no practical hindrance to whole-house PLC networking. This paper has been created to explain why. It has to do with the high operating frequency range of PLC and paralleled line impedances.

The reason for this question goes back to early forms of powerline signaling, such as X-10 devices used for light and small appliance control in the home. These devices operate over a very low carrier frequency (<100 kHz). It quickly became apparent to users that these devices did not work if the sender was on one phase and the receiver was on another. We understand now that the reason these devices did not work across household AC phases is because the low operating frequency was not able to couple across phases. In other words, the impedances existing between phases are too high, causing high signal attenuation.

In sharp contrast to the above, Intellon HomePlug Powerline Communications signals are high-frequency and broadband, operating in the roughly 2 to 30 MHz range. In this frequency range, impedances between phases are low, with some basic RF impedance and transmission-line theory at work.

2. Regional Differences

Some countries, as the norm, provide only a single phase of AC power to a dwelling (home or apartment). This is very common throughout the UK. This is also true for many countries in Europe, the Middle East and across and down through Asia. Where only one phase is employed, the question of cross-phase coupling is irrelevant.

However, some countries in Europe along with Canada and the Americas do supply households with multiple phases. So the question applies to these dwellings in which multiple phases separate AC circuits. With HomePlug Powerline Communications, circuit separation does not cause isolation. Let's look a little closer to see why.

3. Poly-phase AC

Homes in Canada, the Americas, Germany and other parts of Europe are supplied with multiple AC phases, or service lines. The key factors that naturally converge the phases, and associated household circuits, as one Homeplug PLC network are:

- Poly-phase main service lines (mains)
- Poly-phase wiring to appliances in the home
- Inter-winding capacitance at the main transformer

The three key factors listed above act as a high-frequency bridge between phases, due to the low impedances that exist between the intertwined phase lines, closely positioned conductors of poly-phase appliance wiring and inter-winding capacitance of the main transformer. This is illustrated in Figure 1. Even though the Canadian/American two-phase system is shown, the principles of cross-phase coupling also hold true for those cases in which three-phases are brought to the home.

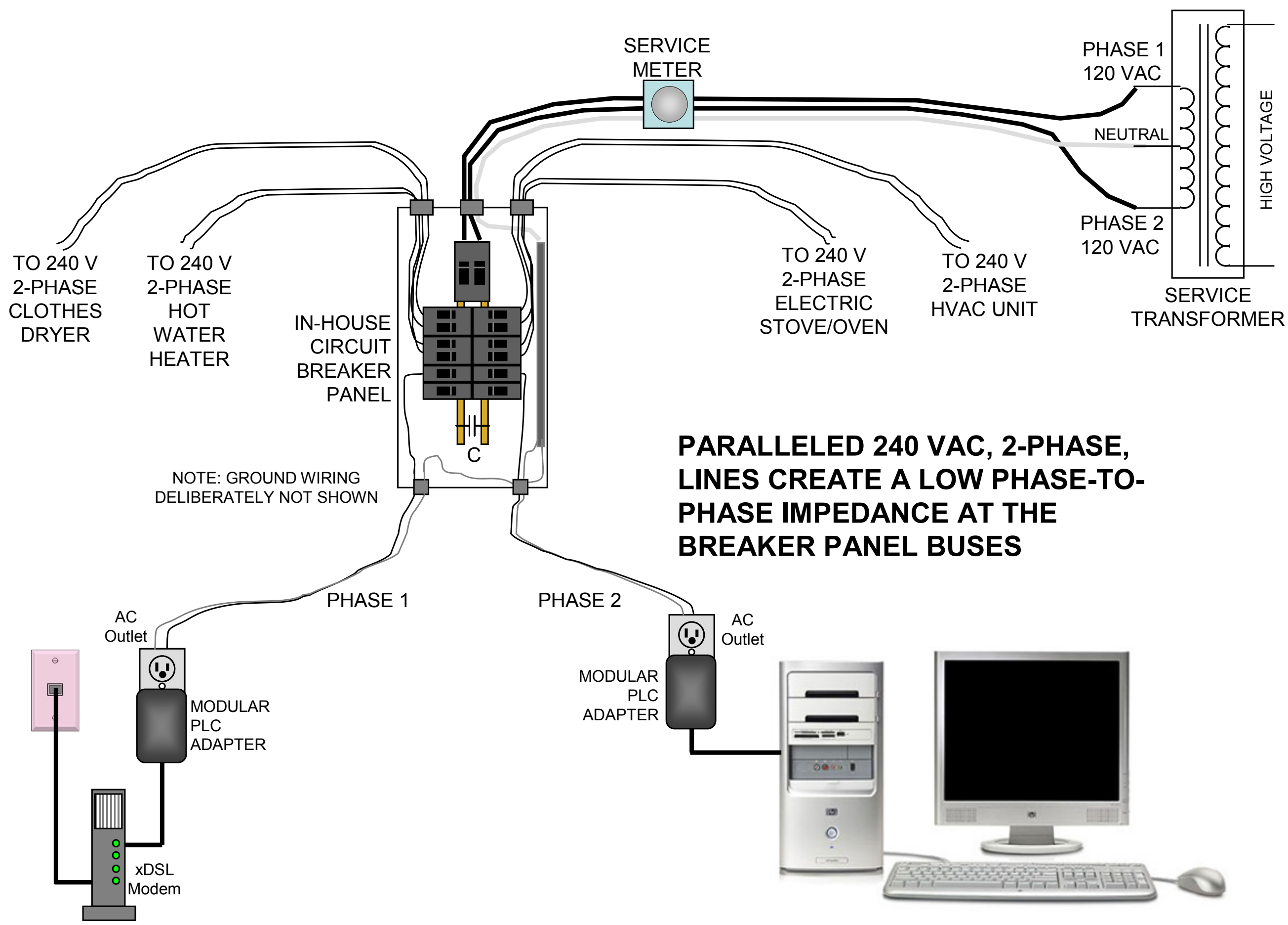


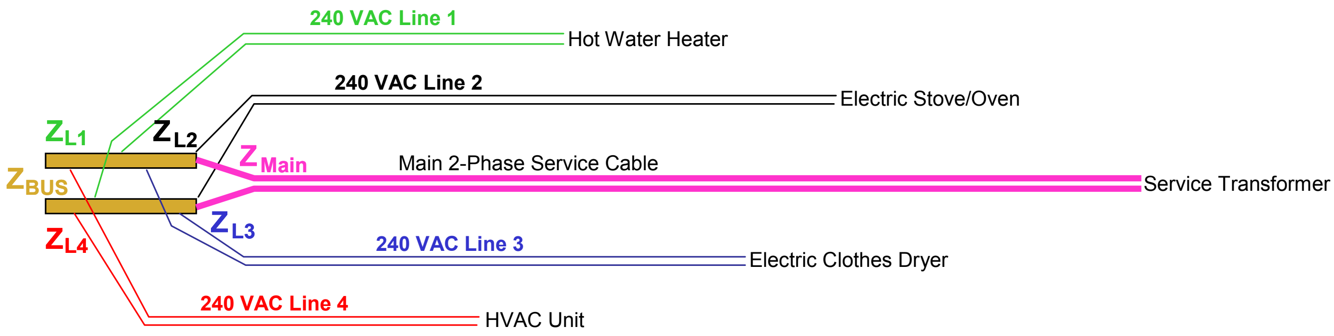
Figure 1: Cross-phase Coupling of PLC Signals

The circuit breaker panel is the point of convergence for the cross-phase coupling. All circuits connect to the same common bus bars via circuit breakers or fuses. The bus bars provide some coupling because of inter-bus stray capacitance.

However, most of the coupling is provided by the paralleled connection of poly-phase cables that lead to major household appliances, and of course the incoming mains. In short, each of these poly-phase cables confers a low impedance across the bus bars because each poly-phase line acts as a capacitor with each conductor serving as a capacitive plate. At frequencies in the HF spectrum, the resulting inter-wire impedance (Z), in the form of capacitive reactance, is low.

The poly-phase mains coming to the home may exhibit a very low impedance because of the additional capacitance contributed by the inter-winding capacitance of the main transformer.

The combined paralleled impedance from these cables at the bus bars (Z_{BUS}) is very low at frequencies in the HF band.



$$Z_{BUS} = Z_{L1} || Z_{L2} || Z_{L3} || Z_{L4} || Z_{Main}$$

Figure 2: Bus Impedance is a Function of Paralleled Poly-phase Lines

The concept of low bus impedance (Z_{BUS}) signal coupling is summarized in Figure 3.

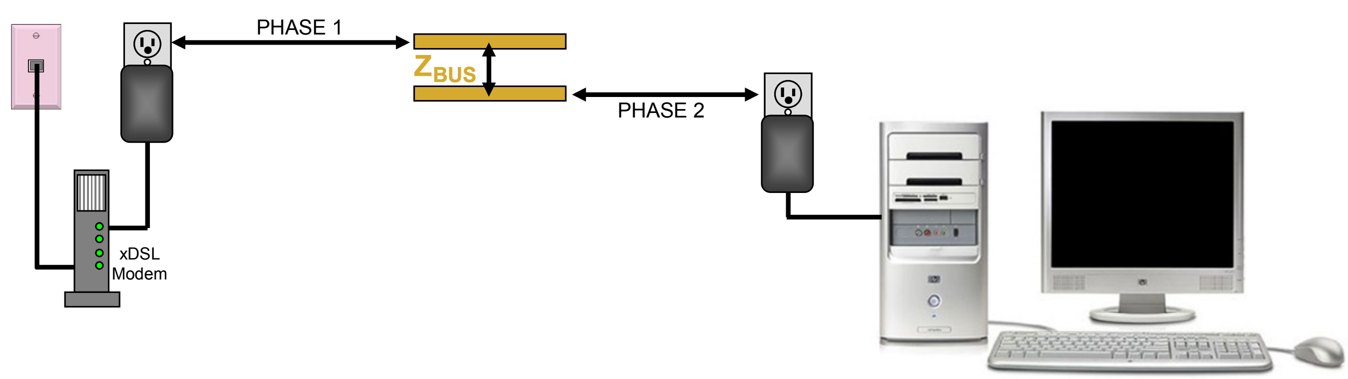
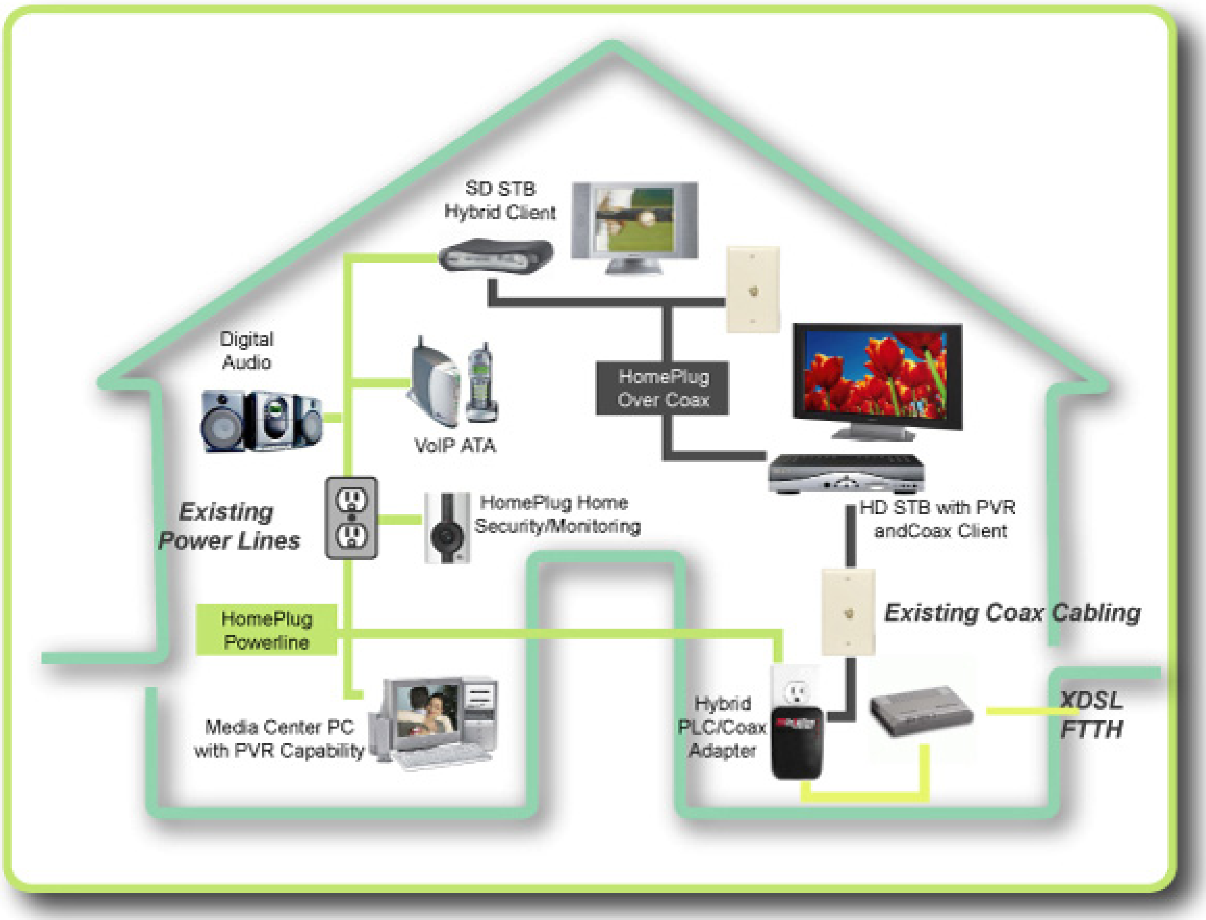


Figure 3: Bus Impedance Bridges PLC Signals Across Phases

The low bus impedance exists regardless of whether a major appliance is actually turned on. With a poly-phase appliance turned on, the bus impedance may drop even lower in the form of a complex impedance. In any case, the bus impedance, Z_{BUS}, is always sufficiently low to bridge Intellon PLC signals across phases without significant attenuation.



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