Belkin F5D4076uk

Radio Interference generated by one model of PLT Adapter And the Flaws of Powerline Telecommunications

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Product Description

The Belkin F5D4076uk belongs to a class of device commonly referred to as "PowerLine Telecommunication" (PLT) and frequently called a PLA (PLT-Adapter). The device is a Modem (***Mo***dulator-***Dem***odulator) and takes computer data and encodes it into a signal which is then injected on to the mains electrical wiring at the users' premises. Two or more devices establish an ad-hoc network, accessible to all devices connected to the PLAs by Ethernet cable. A number of different manufacturers make the adapters and consequently different schemes have evolved to encode the data (modulation) however the one feature all devices of this category share in common is that they use High Frequency (H.F. or Shortwave) signals to transmit and receive the data via the electrical wiring. This is an inherently unsound engineering practice.

The technology is 'relatively' new having originally come to market in around 2003, with comparatively slow data rates by today's standards. The first to arrive on the market typically employed a data rate of 14Mbps (Mega (million) bits per second) and was named HomePlug. This was developed into a "Standard" and became known as "HomePlug 1.0". The HomePlug "standard" or HPA (HomePlug Powerline Alliance) is specified to transmit data from 2 MHz to 30 MHz.

With the inevitable evolution of technology, faster data rates became available over the ensuing years, with HomePlug 2.0 at 85Mbps and HomePlugAV rated at 200Mbps. Over this same period other modulation schemes and speeds have surfaced however these have typically been 85 Mbps and 200 Mbps and broadly fall into line with HPA or UPA (Universal Powerline Association - 2-32 MHz) "standards". The product to which this report relates is marketed as a 1Gbps device although it is not fully compliant with the Gigabit PLT "standard" (G.hn or G.9960 recommendation) which is itself the subject of considerable controversy among EMC Engineers and specialists throughout Europe. The F5D4076 is considered an HPA device which has had its capabilities extended by inclusion of the GIGLE chipset GGL541.

It is a particularly important point to note that the speeds attained by this device, which far exceeds that of its competitors at the time of writing, is achieved by using the VHF radio spectrum in addition to the HF spectrum traditionally used by PLT. As will be demonstrated, this has serious implications for many services which were hitherto not considered threatened by the technology.

The F5D4076uk is marketed as a "Gigabit Powerline HD Starter Kit" and is aimed at the growing population of videophile and high definition users who digitize content onto Network Storage Adapters for streaming content around the home. Secondary markets exist for users who wish to transport broadband and network data around the home or office without resorting to running costly and unsightly Ethernet cabling to create the physical infrastructure required to support a 'conventional' network, where none already exists. The lure of a gigabit connection is quickly gaining mainstream attention, with most modern computers now equipped with Gigabit Ethernet ports.

The technical engineering understanding of this technology does not translate well to layman's terms however in essence, all popular and efficient wire-based communications systems utilise a balanced

arrangement which contains the magnetic properties of an energised wire. This in turn renders it relatively neutral to its environment. PLT however, injects radio frequency signals into a network of cables which are of unknown electrical characteristic at any frequency other than that used by domestic mains power. The result is an inherently unbalanced arrangement which is inclined to radiate the radio frequency energy rather than transport and contain it. Although outside the scope of this document, at the time of writing, many respected organisations have publicly announced their objection or concern regarding this technology; the BBC, NATO, RSGB, EMCIA, IARU, non IT telecommunications working groups of the ITU are to name but a few.

Since Ofcom started keeping records regarding interference from PLA in July 2008, PLT has become one of the largest contributors to Spectrum Abuse complaints fielded by members of the public.

An important aspect of the technology which has been repeatedly overlooked it that even if individual PLT modem models are somehow able to achieve compliance with a conducted Standard such as EN 55022, this is an ideal test scenario and does not reflect the conditions under which the device is to be deployed. The deployment conditions are unique to each house or office and cannot therefore be modelled or included in any announcement to compliance. Electricity mains cabled were designed for one purpose – to convey electrical power.

Product Issues "In-Service"

Once a solitary unit is plugged into a mains socket, it immediately polls for the presence of other compatible devices. Once located, the devices 'handshake' and establish an Ethernet network over the electrical mains infrastructure of the building.

Upon energising one unit, a shortwave radio being listened to in the kitchen immediately began shrieking with a strong pulsing sound, not unlike a fast, perpetual drum-roll. When the second unit of the pair was installed in its intended location (in another room) the pulsing was added to by a loud 'white noise chirping' which continued with alarming frequency, eliminating any remaining intelligibility of radio reception.

As an engineer with a technical background in radio communications I felt it prudent to assess the impact of this device on my communications station located some 25m from the house, with antennas also physically isolated from the domicile. What I discovered was very disturbing indeed and I have subsequently unearthed a significant sub-culture of irate radio users who have all been adversely affected by PLT technology.

After installing the Belkin F5D4076uk it has was impossible to continue with my principal hobby in radio communications until the devices were powered down. I therefore conclude that these devices and any related product of this technology category are not fit for purpose since they cannot operate without causing significant Electromagnetic Compatibility issues. I therefore submit that a sample of devices across the various manufacturers are submitted for formal Compliance Testing to evaluate whether they comply with the Essential Requirements of the EMC Directive (2004/108/EC).

It is a requirement of the EMC Directive that Member States conduct "market surveillance" to determine that products brought to market comply with the Essential Requirements and should non-compliance be detected, action be taken to bring the devices into compliance or removed from market.

Irrespective of any transition periods incorporated into the Directive the overriding requirement found in Article 5 states that:-

ANNEX I
***ESSENTIAL REQUIREMENTS** REFERRED TO IN ARTICLE 5*
1. Protection requirements

> *Equipment shall be so designed and manufactured, having regard to the state of the art, as to ensure that:*
>
> > *(a) the electromagnetic disturbance generated does not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended;*

It should also be noted that paragraph 2 of the Directive places the responsibility for all devices to no interfere with broadcast and amateur radio:-

> *(2) Member States are responsible for ensuring that radio-communications, including radio broadcast reception and the amateur radio service operating in accordance with International Telecommunication Union (ITU) radio regulations, electrical supply networks and telecommunications networks, as well as equipment connected thereto, are protected against electromagnetic disturbance.*

Technical Advice

Subsequently to discovering the significant EMI (electromagnetic interference) issues with PLT and the Belkin in particular, my research has concluded that at the time of writing, Ofcom should not be relied upon for impartial technical advice on PLT. I have been sent a set of Compliance Test results for another PLT product which was also sent to Ofcom by the client of the test and can categorically state that it would be impossible for a PLT device of the current generation or any previous generation to comply with EN55022, the levels in CISPR22 or the ***Essential Requirements*** of the EMC Directive. Despite this, Ofcom continue to publish inaccurate and contrary information on their website regarding the technology, to the dismay of the the Radio Society of Great Britain who represent the 65,000 licensed Amateur Radio operators in the UK. There is a significant opposition to PLT from persons and organisations with technical competence in this area and many of these have now publicly decalared that they believe Ofcom to be not fit for purpose.

Further research has uncovered that the UK's BIS and the European DG Enterprises have been completely sold on the PLT technology as an integral part of the larger vision for the delivery of digital content, such as in the UK Government's 'Digital Britain' vision.

For this reason it is suggested that for any technical advice regarding the technology or application of Standards, correspondence should be confined to neutral parties which have no vested interest in the commercial aspect of PLT, or Regulation. One of the many Notified Bodies, the EMCIA or an EMC Consultant with no connection to the PLT industry would be recommended.

The Belkin Experience: Field Tests

What follows next was carefully compiled from my personal experience with the F5D4076uk.

Purchased Friday 12/3/2010 from Argos, Shepton Mallet.

Product Make:	Belkin
Product Name	Gigabit Powerline HD Starter Kit
Rated Speed	1 Gbps
Product Part No.	F5D4076uk
Product Serial Numbers	160943B4604134 160943B4604135
Certification Claimed:	FCC Part 15 CE Stamped but no certification data EN60950
Standards Claimed:	802.3 802.3u HomePlugAV
Other Info:	xtendnet™

First observation is that the device is certified to comply with EN 60950 but fails to display a double square (double insulation) symbol thus immediately fails this compliance aspect.

Unit was installed to the manufacturer's specifications as per the manual, using the Ethernet cables provided. One device was at the Router position in the front Hall and the other behind a sofa in living room. At the router a 'network media storage device' containing digitised movies is also connected to the router. The second PLA in the living room was connected to an EMC 'conditioned' (clean) laptop via Ethernet and the WLAN terminated to ensure a single network path.

The interference presents as a broadband 'white noise' "chirp" with bursts typically 0.2s - 5s long separated by intervals of less than two seconds at most and 0.5s typically.

Initial observations.

Units were plugged in, behaviour within anticipated parameters according to the manual. Shortwave radio in the house tuned to 17 MHz became overwhelmed with strong impulse noise, rendering the radio unusable over significant areas of the HF spectrum.

Field Tests

Test 1. Only one adapter is plugged into a socket and energised. It was not connected via Ethernet to any clients and thus existed as a solitary, unconnected device which would poll for other PLA units with which to connect. This was undertaken to simulate the condition which would present if the operator or another

person, routinely or inadvertently turned one adapter off at the mains but left another running; this is anticipated to be quite a common scenario.

Test 2 comprised both adapters plugged in, energised but no client connected via Ethernet. This is the default 'idle' condition.

Test 3 involved having the adapters energised, streaming a high definition video (20GB, 15Mbps) from network storage to the laptop which played the file on its media player.

The Victim Receivers were a Yaesu VR-500, with a 30cm telescopic antenna. As with all EMC tests the mode was AM (Amplitude Modulation). Some measurements were also taken using a Thurlby-Thandar PSA1301T spectrum analyser, a small stand-alone DAB radio with a telescopic antenna and a stereo FM broadcast receiver. At the shack (radio communications room) 25m from the house and thoroughly filtered for conducted emissions, some observations were also made with a FlexRadio Flex-5000 SDR and a QS1R Quicksilver SDR with a broadband vertical, OCFD Windom and a multiband folded dipole; antennas average 25m from the house.

Test 1

The initial response from the Victim Receiver (VR-500) was a very high signal of impulse noise, indicating considerable field strength. The telescopic antenna had to be retracted to 10cm whilst inside the house in order to obtain a signal strength which was more indicative of the emissions, without overloading the receiver. In this condition, emissions were observed from the receiver's lowest operating frequency of 0.1 MHz and continued almost continuously to 370 MHz, only attenuated but not completely absent from around 30 MHz to 50 MHz. This indicates that the condition known as intermodulation has occurred which results in the dilution of spectral purity and thus observable signals outside the range of the device's specified transmission bounds (2 – 30, 50 – 300 MHz).

Notching was in place for the HF amateur bands including 60m but appeared notably absent from the 6m, 4m, 2m amateur bands, the VHF Aeronautical band, the DAB band, VHF FM Broadcast and Business Radio regions. Our DAB radio with a typically average signal for a semi-rural location was unable to function as intended; normally working without interruption it was unable to receive a continuous, unbroken stream and ruined listening enjoyment for the duration of the Belkin tests.

The shack radios had no trouble observing the impulse emissions from the solitary Belkin, with an average signal of -73dBm from 2.5 MHz to 28 MHz. Wideband spurs were also observed at 50.2 MHz (6m amateur band) and 70.3 MHz (4m amateur band). No other antennas were available for checking other frequencies.

Test 2

With both adapters connected and synced, there did not appear to be any significant variation from the observations of Test 1.

Test 3

With the adapters engaged in transferring data continuously, the profile of the interference altered significantly. In this condition, the adapters continued to make the impulse popping, typical to this

modulation scheme but also added to this, loud and almost constant bursts of a 'white noise scream', broken by brief intervals of up to a second or two. Whilst in full transfer, an observer with no technical background would most probably consider this as the noise floor, unaware that the prevailing signal levels are an order of 20-30dB higher, thus masking legitimate signals and the legitimate noise floor. The impulse occurs at a very cognitive level and is chronically irritating.

At 10m from the outside wall of the property, the emissions were clearly audible at a high strength from 2.5 - 28.0 MHz and from about 75 - 309 MHz. The 4m and 6m amateur bands also presented with increased noise and obvious spurs which are not present while the modems are powered down.

At 30m from the outside wall of the property, the emissions were still clearly abundant across the HF range however in VHF, the magnitude of emissions became more cyclic in nature over the established interference frequency range, as one would expect from an antenna system (house mains) whose impedance and efficiency varies with frequency.

As the distance increases, the presence of VHF emissions diminishes slowly, since the efficiency of the radiating system will vary according to the prevalent conditions in the electrical installation. One spur was chosen at random; 290 MHz and this was still present at 100m distant from the source, with a simple 30cm telescopic antenna.

Tests at the radio communications room (shack)

Test 4

This was conducted at a dedicated radio communications room 25m from house. The Belkin units remain installed in their original location. The Victim Receiver was a Flex-5000a SDR with calibrated levels.

With a horizontal folded dipole antenna, resonant on 14, 18, 21, 24, 28 MHz, at 14 MHz, 100kHz from interference acquisition frequency the noise floor is -105dBm; and rises quickly as one tunes down, away from the 20m amateur band and peaks at 13.5 MHz at -83dBm; this tapers as one tunes away from antenna resonance.

The interference appears notched at the 20m Amateur band.

At 17.3 MHz this broadband noise increases in amplitude as one continues to tune from the frequency of initial acquisition and 500 kHz from acquisition the noise bursts are at -95dBm. The interference amplitude continues to rise until a sharp notch at 17.990 MHz. At 10 kHz below this the burst amplitude has risen to -85dBm.

The notch for the 17m amateur band appears good.

Pulse noise appears at 17.900 MHz identical to the 'idling' noise observed on the shortwave radio which first suffered interference. The Belkin interference then reduces in amplitude approaching the 17m amateur band
Interference is reacquired at 18.255 MHz and quickly rises in amplitude to -85dBm by 18.297 MHz. As expected with a resonant antenna, the noise tapers away by 20.000 MHz.

The interference appears notched at the 15m Amateur band.

Interference is reacquired at 21.550 MHz however reception at this area of spectrum problematic due to Spectrum Abuse from nearby BT Vision installation utilising Comtrend PLAs. Despite this the BT Vision interference was clearly being modulated by the Belkin interference and in many places the Belkin established dominance.

Continuing to tune the interference is once again observed at 24.445 MHz and continues to increase in amplitude to -93dBm at 24.781 MHz.

The interference appears notched at the 12m amateur band.

Reacquisition of the interference is observed at 25.080 MHz and rises extremely quickly over 20 kHz. At 25.216 MHz the amplitude is at -92dBm and again slowly tapers away due to antenna resonance and is not again observed above 27.000 MHz.

Test 5

The following test was conducted on an 'Off-Centre Fed Dipole' which is suspended 13m above ground between a support mounted on the rear of the property and the main station mast located beside the radio communications room. With exception for a short catenary wire of approximately 3m between the house and an outside brick walled shed, the bulk of the electrical supply is underground in a shielded cable.

Observation on this antenna is chronically hampered by the Spectrum Abuse from a BT Vision installation using Comtrend PLAs, nearby. It should be noted that the BT Vision interference averages -87dBm on this antenna and any interference from the Belkin will need to equal or exceed this due to the strong modulation type of the Comtrend adapter used with BT Vision.

Belkin interference is first acquired at 5.515 MHz by 5.537 MHz the amplitude has risen to -82dBm and -78dBm at 5.680 MHz. The interference continues at this level through the broadcast band but subsides below the inherent BT Vision noise by 6.300 MHz.

At the time of test it was not possible to find a clear frequency in the 40m amateur band to determine if the notch was effective.

The Belkin was reacquired at 7.980 MHz where it clearly emerges as the dominant source of interference at -78dBm. The interference is continuously present through to 9.540 MHz where it is superseded by the BT Vision interference. Between 7.9 MHz and 9.5 MHz levels are as high as -73dBm. The Belkin interference once again dominates above 9.9 MHz and is present right through the 10.000 MHz international time signals but quickly tapers off just above this to accommodate the 30m amateur band.

The interference appears notched at the 30m amateur band.

The Belkin is reacquired at 10.240 MHz and quickly rises in amplitude. By 10.300 the level is at -80dBm. These levels continue with unbroken coverage to 13.900 MHz.

The interference appears notched at the 20m amateur band.

Once again the Belkin interference is reacquired at 14.440 MHz and remains the dominant source of interference continuously through to 17.975 MHz where it notches for the 17m amateur band. At 17.965 MHz the level is at -84dBm.

The interference appears notched at the 17m amateur band.

After the 17m amateur band the interference resumes as dominant at 18.270 MHz and has risen to -83dBm by 18.358 MHz. At 19.000 MHz the 'idling' sound present on the shortwave radio in the house becomes evident in addition to the burst noise. By 19.920 MHz the burst signal level is now at -73dBm. The interference continues unbroken to 20.930 MHz and peaks at -71dBm at 20.852 MHz.

The interference appears notched at the 15m amateur band.

Resuming at 21.520 MHz, the Belkin interference rises sharply from the -97dBm noise floor on 20.500 MHz to -81dBm at 21.555 MHz and continues unbroken coverage to 24.800 MHz.

The interference appears notched at the 12m amateur band.

Following the 12m amateur band the interference resumes at 25.050 MHz and again rises sharply to level circa -80dBm until quickly tapering off at 27.930 MHz (half way through the CB Radio band) to make way for the 10m amateur band.

There is no evidence of the interference above 28 MHz.

Test 6

Conducted on a broadband vertical antenna, 7m tall, mounted 4mabove ground level and sited 27m from the house and 3m from the radio room. The vertical antenna is broadband by design and is not specifically resonant on any band. This is the first and only test with a vertically polarised antenna.

The test location is beset with chronic interference from nearby multiple BT Vision installations and consequently the table below indicates the observed noise floor at the time of the test and in most instances this noise floor is artificially high due to the presence of PLT interference from neighbours. As such the difference between the level of interference caused by the Belkin and the 'natural' noise floor is impossible to determine without cessation of all nearby PLT devices. This is indicated by "(BT Vision)" next to the observed reading.

The Belkin interference is first acquired at 6.490 MHz and follows the same pattern observed in the other antenna tests with regard to amateur band notching. This test will simply observe some of the levels over the HF frequency range.

Frequency MHz	Level (dBm)	Noise Floor (dBm)
6.8	-85	-90 (BT Vision)
7.5	-85	-95 (BT Vision)
8.5	-86	-94 (BT Vision)
9.5	N/K	-89 (BT Vision)
10.5	-87	-95 (BT Vision)
11.5	-83	-92 (BT Vision)
12.5	-78	-94 (BT Vision)
13.5	-83	-93 (BT Vision)
14.5	-87	-98

15.5	-84	-97 (BT Vision)
16.5	-85	-99 (BT Vision)
18.5	-78	-104 (BT Vision)
19.5	-85	-106 (BT Vision)
20.5	-83	-105 (BT Vision)
22.5	-78	-107 (BT Vision)
23.5	-79	-106 (BT Vision)
24.5	-77	-107
25.5	-86	-108
26.5	-87	-110

Conclusion

High Frequency, H.F. or shortwave as it has colloquially become known is a part of the electromagnetic spectrum with unique characteristics insomuch that due to ionospheric refraction, signals transmitted in this part of the spectrum can 'bounce' numerous times from atmosphere to ground and back up. In this way radio transmissions can travel very long distances and in peak conditions have occasionally circumnavigated the globe back to its origin. Because of this property shortwave has been classified by international agreement as a natural resource and consequently international agreements exist to ensure coexistence between users , services and administrations.

During times of national emergency in any country, it is notably the Radio Amateurs who underpin emergency communications. The Asian Tsunami, Haitian earthquake and 9-11 are just a tiny proportion of events where Amateur Radio has played an enormous role in ensuring clear communications in times of great need. In contrast in 2008 an emergency relief exercise in Linz, Austria had to be abandoned due to PLT interference. Had that been a genuine emergency the consequences would have been dire.

As PLT continues to be deployed, the noise levels steadily rise and one by one the amateurs become disenfranchised. More concerning is that every 11 years or so, activity in the sun has enormous effects on radio wave propagation and signals with very low energy can propagate around the world. To date there has not been a coincidence between a solar maximum with PLT deployed in any number but should we arrive at 2014 with a huge PLT population, the consequences for many services including civilian aeronautical emergency communications, military, commercial and many, many others may find it impossible to operate due to the inherent levels of interference being caused by a source which could be avoided if action is taken now, before it is too late. This is reflected in the recent paper; ***Environmental Effects of the widespread deployment of high speed Power Line Communication; Cumulative Effects on Signal/Noise ratio for Radio Systems*** By Richard Marshall, MA, CEng., FIEE, FIET, FInstP. (Issue 87, The EMC Journal, March 2010)

PLT came to market by surreptitiously making its Conformance Declaration using the Technical Construction File but unfortunately for the Regulators, it was realised too late that the companies involved cited a non-existent standard for their technical documentation - CISPR/I/89/CD which was discredited and acrimoniously removed from the IEC's website in 2003 – never to be seen again; even so, when cited it was only a Committee Draft and thus not a citable standard. With a foot in the door, huge sums of money were used to lobby political areas susceptible to pliancy and this succeeded with DG Enterprises supporting a move to postpone alterations to EN55022 which would have shown the world the reality of PLT non-compliance.

At this point it seems we are locked into an auto piloted heading of destruction propelled by corporate lobby which has successfully convinced those who 'matter' into believing PLT is the way forward, just for the sake of profit. Since the communication regulator is now unable (or unwilling) to undertake its Statutory Duty to protect the Spectrum and its Stakeholders, the public must now look to other agencies for its protection via Market Surveillance.

Please have a sample of PLT devices tested by an independent entity – preferably a Notified Body with specific emphases placed on Conducted and Radiated Emissions to the current European limits which apply to all electronic goods. The results will speak for themselves.

I recommend the adapters supplied with BT Vision (Comtrend) are included since these have proven particularly polluting and resulted in these adapters being responsible for Ofcom's highest recorded rate of interference complaints of any device to date.