

Experimenting with High-Speed Wireless Networking in the 420 MHz Band

David Bern, W2LNX
Montgomery College, Rockville, Maryland
W2LNX@arrl.net

This paper reports on our testing the Doodle Labs DL435-30 and Xagyl Communications XC420M wireless networking miniPCI cards. They behave like IEEE 802.11 wireless networking cards but operate in the 420 MHz band. We have successfully tested these cards over 10 miles at about three Mbit/s data rate at a 5 MHz bandwidth in the 420 to 426 MHz ATV sub-band. Our test applications were a Webcam video streaming program and a file download server program that ran on inexpensive netbook computers.

Keywords: 420 MHz, DATV, IEEE 802.11, miniPCI, TCP/IP, wireless networking

Introduction

At the 2011 Digital Communications Conference, Charles, G4GUO and Ken, W6HHC presented their DATVexpress project [Brain 2011] as a less expensive hardware and software solution for digital amateur television (DATV) in the 1.2 GHz band. It made me wonder: would it not be simpler to focus on creating a high-speed network and use a Webcam on a personal computer to stream video to another personal computer? Can a DATV system be assembled using only purchased commercial off the shelf components (COTS) and not have to design any custom hardware and software?

At the beginning of this year, I mentioned this problem to Chris, KB3CS, a fellow member of the Montgomery Amateur Radio Club (MARC), Rockville, Maryland, and he suggested that I take a look at the Doodle Labs 420 MHz high-speed data radios for amateur radio [Doodle]. Doing a Google search on “Doodle Labs”, I found a blog entry by Steve, KB9MWR about these data cards [KB9MWR 1]. In it, he references a short video by Kyle, N0KEW where he demonstrated a speed test using these radio cards [N0KEW]. Then, I found a detailed description by Joseph, N9ZIA on how to use a DL435-30 in a Ubiquiti RouterStation Pro with its DD-WRT firmware [N9ZIA]. Clearly other hams were starting to experiment with the Doodle Labs cards and DD-WRT [DD-WRT] and this prompted me to order some cards from Singapore.

Learning to use the Ubiquiti RouterStation Pro router boards

While waiting for the DL435-30 cards to arrive, I ordered some Ubiquiti RouterStation Pro router boards [RS Pro], MMCX male to N female connector pigtails [pigtail] for the cards, and several Wistron CM9 Wi-Fi miniPCI cards from mini-box.com [Wistron] and from eBay. The RouterStation Pro boards were reflashed with their DD-WRT firmware using TFTP [reflash] and the Wistron Wi-Fi cards were temporarily installed with Wi-Fi antennas. Now, I was ready to learn DD-WRT. In theory, the DL435-30 and the XC420M cards are drop-in replacements for the Wistron 2.4 GHz Wi-Fi cards. As Daniel Lajeunesse of Xagyl Communications explained to me, these cards are designed with the Qualcomm Atheros AR5414A chipset followed by a transverter stage from 2.4 GHz to the 420 MHz band. My first exercise was configure a RouterStation Pro router as a Wi-Fi client in Client Wireless Mode [client] so it can access our household Wi-Fi access point. The second exercise was to configure another RouterStation Pro router as a Wi-Fi access point in AP Wireless Mode [AP] with its own SSID so it can be found and accessed by my laptop. That done, the client router was now able to connect to the access point router.

Learning to use the Doodle Labs wireless networking cards

When the Doodle Labs DL435-30 cards arrived, I built two quarter wave antennas cut to 422.5 MHz; an antenna pigtail and a large tuna fish can was used as the ground plane and base. The SWR of the antennas were trimmed with my MFJ-269 antenna analyzer to be less than 1.5:1 [W2LNX]. Then, I replaced the Wistron cards with the Doodle Labs cards in both router boards and attached the MMCX antenna pigtails to them. On the access point router DD-WRT Wireless Physical Interface ath0 page, the Wireless Channel was set to 1 - 2412 MHz that actually set it to 422.5 MHz, the Channel Width was set to Quarter (5 MHz) and The Wireless Network Name (SSID) was set to BOARnet¹. Also, Security Mode was set to Disabled on the Wireless Security ath0 page. On the bottom of the client router DD-WRT Wireless page under Access Point, the access point router board appeared. Both router boards needed to be set to the same SSID. Clicking on Site Survey button on the bottom popped up a Neighbor's Wireless Networks page showing the BOARnet SSID. Then, clicking on its Join button set the client router to have this SSID.

Learning to use the Xagyl Communications wireless networking cards

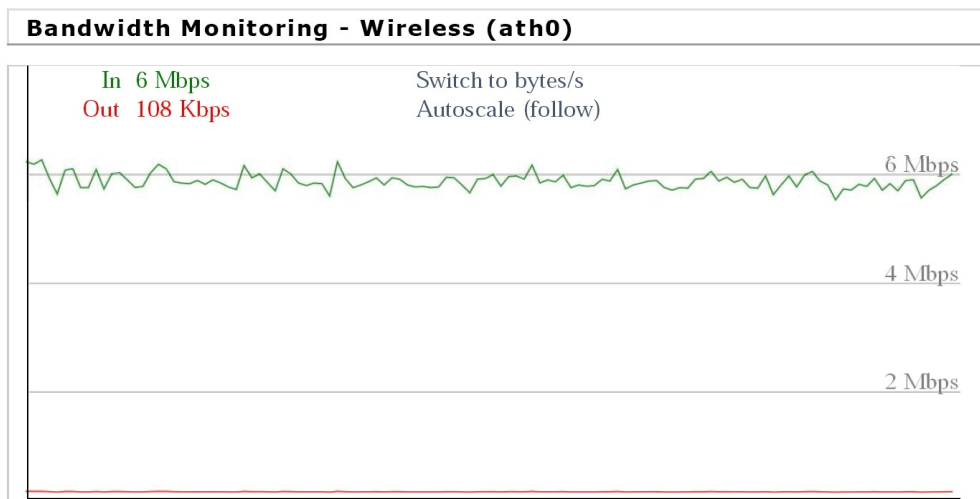
In March, I was alerted by Steve that Xagyl Communications was shipping their of 420 MHz XC420M miniPCI cards [KB9MWR 2]. In April, I replaced the Doodle Labs cards on the router boards with the Xagyl cards [Xagyl] when I received them. The only change required for the Xagyl cards was setting the frequency in the access point router

¹ Broadband Over Amateur Radio network

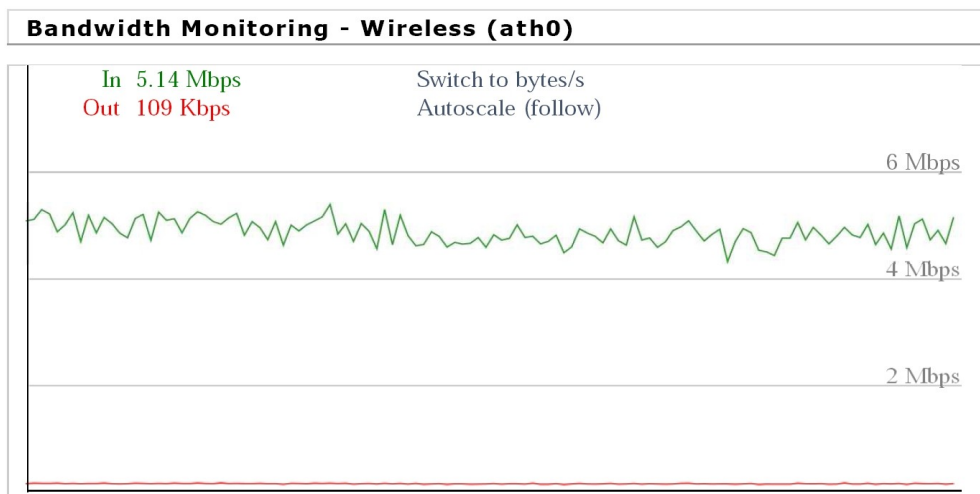
to Wireless Channel 2 - 2417 MHz that set it to the same frequency of the Doodle Labs cards.

Test applications

The test applications were the hfs file download server [hfs] and the Yawcam Webcam program [Yawcam] that I learned about in a recent QST article [microscope]. Yawcam has a built-in Web server that streams video from a Webcam and I needed a video application since I am testing in the 420 to 426 MHz ATV sub-band [band plan]. For testing purposes, a built-in Webcam in a netbook computer is sufficient. For better video quality, I purchased a pair of Logitech Webcams [Webcam] as mentioned in the QST article. A file download at 20 feet apart from one room to another ran at about 6 Mbit/s for the Doodle Labs cards – see screenshot 1 – and about 5 Mbit/s for the Xagyl cards – see screenshot 2.



screenshot 1: Doodle Labs XC420M cards 20 feet apart



screenshot 2: Xagyl Communications XC420M cards 20 feet apart

Assembling the stations

The access point and client router boards were each put into a lightweight metal cookie box [tin box] mounted with metal standoffs [standoff]. The plastic windows of the lids were replaced with aluminum window screening to provide shielding and ventilation. A female N connector pigtail [pigtail] and a $\frac{3}{4}$ inch PVC pipe adapter for passing through an Ethernet cable were mounted at each end of both boxes. The Ethernet cable, in addition to being connected to the WAN port, also provides power with a power-over-Ethernet power supply [POE 48]. For testing purposes, the quarter wave antennas were attached to the boxes – see photo 3.



photo 3: router with quarter wave antenna and stand

Both routers were configured to allow remote Web page access to the routers via the WAN port. This allows LAN and WAN access over the same Ethernet port. Next, the router boxes were attached to two foot pieces of one inch PVC pipe with cable ties. Thick pieces of Styrofoam board on the back of the boxes prevented them from slipping on their pipes. 11 element 420 MHz M2 Yagi antennas [M2 Yagi] were attached to the PVC pipes with PVC pipe T joints. The routers and the antennas were connected with custom made 18 inch LMR-400 coax cables [The RFC]. The routers needed to be connected close to their antennas since the output power of their cards is about half a watt. These

assemblies easily fitted on top of an eight foot painter's poles – see photo 4.

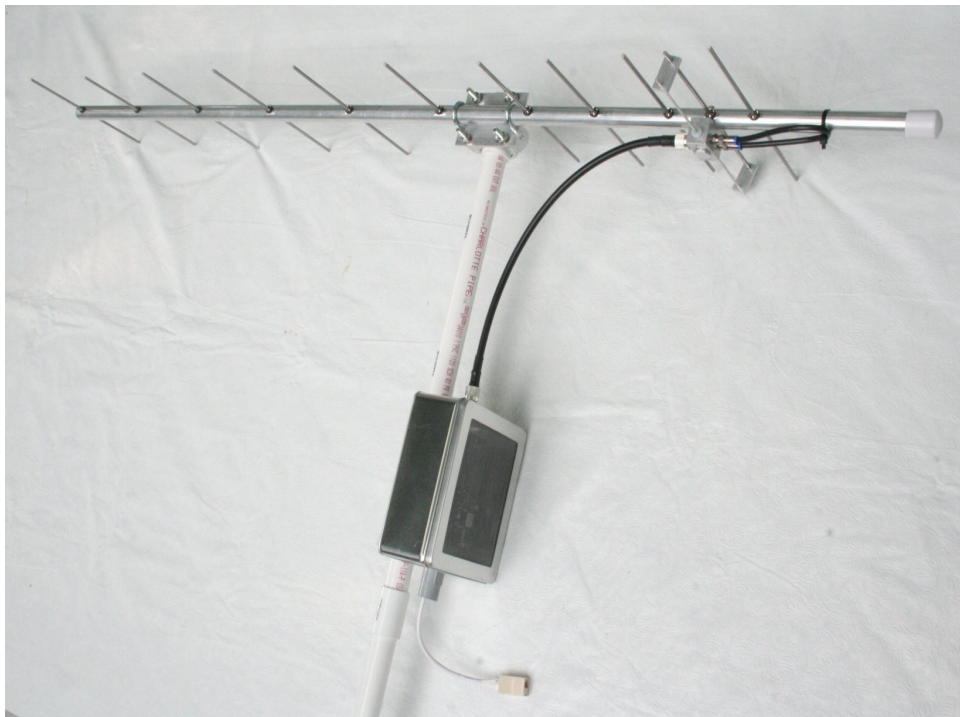
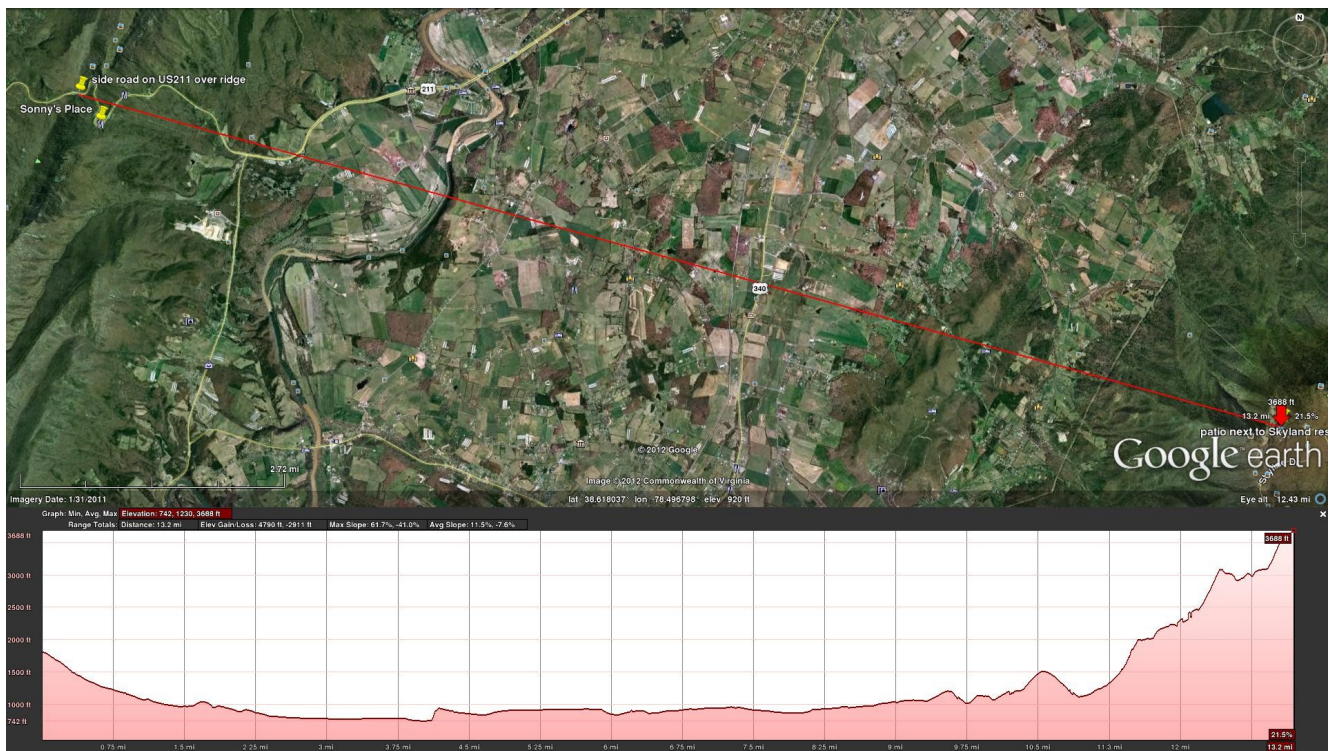


photo 4: M2 420 MHz Yagi antenna with router

Range testing in Shenandoah Valley

The Doodle Labs and Xagyl Communications cards work well from one room to another room in my house and around the neighborhood within a mile of my house. But the real question remained: how well do these data radios work over long distances? The acceptance test I chose was to have at least one Mbit/s data rate over at least a 10 mile distance. I wanted to find two locations that have easy driving access, are within line of sight of each other and are a little more than 10 miles apart.

The July 2005 QST article by David, KD9LA [KD9LA] suggested that Shenandoah Valley is a good place to do a 10 mile range test. Using Google Earth [Earth], the first location I found was the patio next to the Skyland Resort Pollock restaurant in the Shenandoah National Park at an elevation of about 3,650 feet. The other location I found was the parking lot of Sonny's Place restaurant at an elevation of about 1500 feet on US Route 211 about 13 miles away on the other side of Luray, Virginia – see screenshot 5.



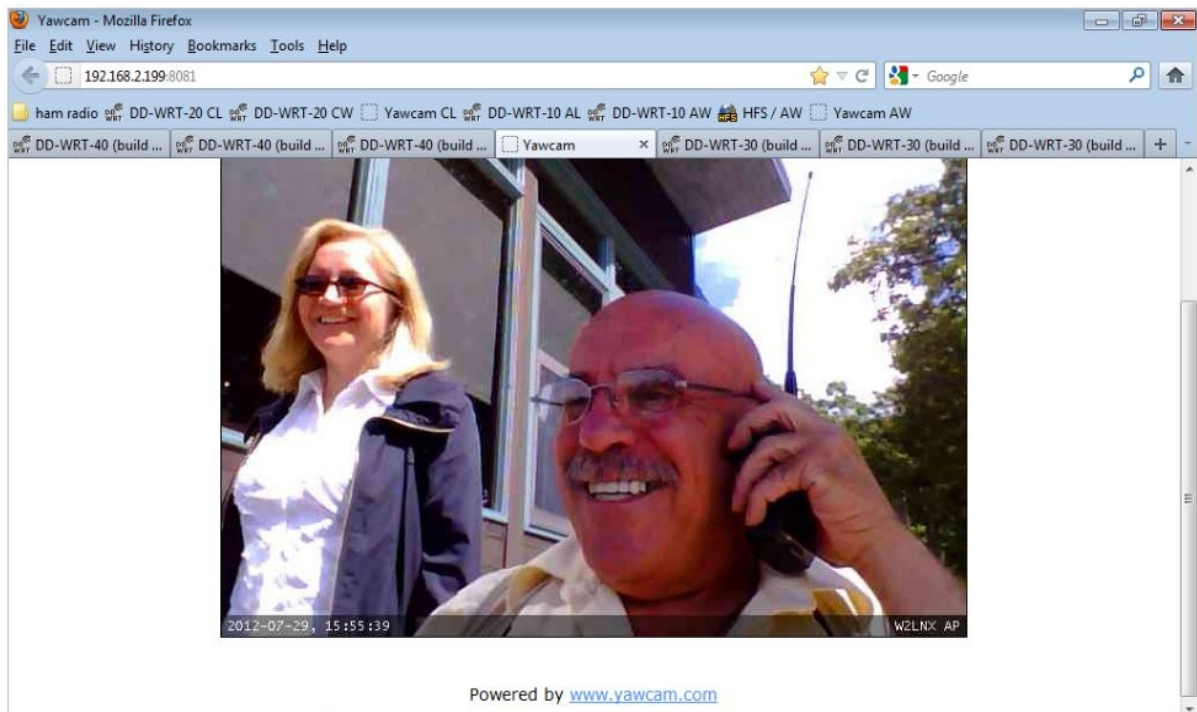
screenshot 5: Skyland to Sonny's Place and to the top of the ridge

In early July, Aleks, KB3YHT, and I drove to the Skyland location and we set the client router with a Xagyl card and the M2 Yagi antenna on top of an eight foot painter's pole secured with a heavy patio umbrella base. On the patio, the antenna was oriented in a northwest direction towards Sonny's Place. Similarly, at Sonny's Place parking lot I set up the access point router with a Xagyl card. As soon as my Web browser accessed the router Wireless page, I saw the client router immediately appear in the Clients list with a signal quality of about 35%. On the Bandwidth page, it showed a data rate of 2.5 Mbit/s from a file download running at about 300 Kbyte/s from hfs while Yawcam was also running at several frames per second.

At the end of July, Aleks, KB3YHT, Vic, WB2U, William, W3QX and I went back to the Skyland patio to duplicate the previous test but with the Doodle Labs cards. While, Aleks and Vic were waiting on the patio – see photo 6, William and I drove to where US 211 crosses over the Massanutten Mountain at about 1800 feet which is a little further and higher than Sonny's Place – see screenshot 5. We obtained similar results of signal quality of about 35%, a data rate of 4.5 Mbit/s from a file download running at about 400 Kbyte/s from hfs while Yawcam also was running at several frames per second – see screenshot 7. Note that the Doodle Labs and Xagyl cards are not compatible since they cannot communicate with each other.



photo 6: Aleks and Vic on the Skyland patio



screenshot 7: Aleks and Vic on Yawcam

We are planning to duplicate the 2.4 GHz range tests originally done by Jason, N4DSL and his fellow hams [KD9LA] on 420 MHz from Reddish Knob in the George Washington National Forest to the Two Mile Overlook 34 miles away and the Hogsback Overlook 56 miles away both on the Skyline Drive in Shenandoah National Park. We expect to be successful with these tests with an array of a pair of 420 MHz Yagi antennas. Even though the array has less gain than a 2.4 GHz parabolic grill antenna, this loss of gain is offset by a smaller path loss on 420 MHz [path loss]. We want to accomplish these tests in time to report our results to the 2012 Digital Communications Conference [DCC] in Atlanta, Georgia.

Conclusions and recommendations

We can confidently claim that the Doodle Labs DL435-30 and the Xagyl Communications XC420M wireless networking cards on 420 MHz work as advertised. They have comparable performance since they easily passed our acceptance test of one Mbit/s data rate over a 10 mile distance. The Doodle Labs cards appear to have a faster data rate, but in North America, the Xagyl cards are more conveniently available since they are shipped from a U. S. address or a Canadian address and they were 35 percent less expensive than the Doodle Labs cards at time of purchase.

We have demonstrated that it is possible to assemble a long distance high-speed data link on 420 MHz with only purchased available components. The only construction required was to make quarter wave antennas and to drill holes in lightweight metal boxes.

Continuing work

Much work still needs to be done on this project. In the short term we want to:

- Create a network of three routers. A router board would be configured as a wireless networking bridge with an omni-directional antenna or with two Yagi antennas pointing in opposite directions. It would allow us to extend the range of a link between an access point router and a client router.
- Evaluate the Avila GW2348-4 [Avila] and the ALIX alix2d13 [ALIX] router boards. These boards have been purchased since they can run DD-WRT and are currently being sold by their manufacturers. The Ubiquiti RouterStation Pro router boards can run DD-WRT but have been discontinued.
- Test the x86 version of DD-WRT on an Intel Atom motherboard using a PCI to miniPCI adapter to determine if an inexpensive low-power consuming motherboard running DD-WRT or a more generic Linux distribution can be an

effective router.

- Internetwork with distant ordinary 2.4 GHz Wi-Fi wireless local area networks or distant ad-hoc 2.4 GHz mesh networks running mesh software such as HSMM-MESH™ [HSMM-MESH].
- Determine if bi-directional linear broadband amplifiers (BDA) for the 420 to 432 MHz range are needed.

A long term goal of this project is to improve our county's public safety backup communications. We are planning tests to determine the feasibility of a self-contained wide area high-speed wireless network for our county's existing data infrastructure.

The dream of creating a national ham radio high-speed data network is alive and, more importantly, this technology can enable building this network. We will continue to report the progress of this project in the TAPR PSR online magazine [PSR].

I would like to hear from others who are experimenting with high-speed wireless networking on 420 MHz. DD-WRT access point router and client router configuration files and information on how to configure a computer connected to its router are available. Please email requests, questions, ideas, suggestions and to W2LNX@arrl.net.

David Bern, W2LNX
Potomac, Maryland, USA
July 31, 2012

ACKNOWLEDGEMENTS

Abbey Alpern, N3WKO, the XYL who put up with this project for the past six months.

Afy Shahidi, my health and wellness coach who helped me find more personal energy.

Aleks Rohde, KB3YHT, who assisted me with our initial range tests and who is one of Shenandoah Valley range testers.

Chris Sylvain, KB3CS, who first suggested that I take a look at the Doodle Labs 420 MHz cards.

Daniel Lajeunesse of Xagyl Communications, who enlightened me how these cards work.

David Fordham, KD9LA, who inspired us with his June 2005 QST article.

Gene Rudolph, General Manager of the Skyland Resort at Shenandoah National Park, who graciously allowed us to set up on the patio next to the restaurant.

Jason Armentrout, N4DSL, who is very helpful in guiding us where to go in Shenandoah Valley.

Jason Boyer, N6EY, M2 Antennas, who educated me about UHF antennas and antenna arrays.

Joel Knoblock, W3RFC, The R.F. Connection, whose custom cables and adapters make this project possible.

Nancy Cross, who graciously let us stand in front of her house on Massanutten Mountain, Virginia during our 13 mile test.

Steve Lampereur, KB9MWR, who writes on the Web about digital communications topics to help advance amateur radio.

Vic Nardo, WB2U, who first brought to our attention the June 2005 QST article and who is one of the Shenandoah Valley range testers.

William Hatfield, W3QX, who enthusiastically supports this project and who is one of the Shenandoah Valley range testers.

REFERENCES and RESOURCES

[ALIX] ALIX alix2d13 System board, PC Engines GmbH,
<http://www.pcengines.ch/alix2d13.htm>

[AP] Wireless Access Point, NewMedia-NET GmbH,
http://www.dd-wrt.com/wiki/index.php/Wireless_access_point

[Avila] Avila GW2348-4 Network Platform, Gateworks Corp.,
<http://www.gateworks.com/products/avila/gw2348-4.php>

[band plan] Band Plan, ARRL, Newington, Connecticut,
<http://www.arrl.org/band-plan-1>

[Brain 2011] Brain, Charles, G4GUO, and Ken Konechy, W6HHC, DATVexpress – a Lower Cost Approach to DATV, TAPR and ARRL 30th Digital Communications Conference 2011 Proceedings, ARRL, Newington, Connecticut

[client] Client Mode, NewMedia-NET GmbH,
http://www.dd-wrt.com/wiki/index.php/Client_Mode

[DD-WRT] DD-WRT is a Linux based alternative OpenSource firmware suitable for a great variety of WLAN routers and embedded systems, NewMedia-NET GmbH,
<http://www.dd-wrt.com/site/index>

[Doodle] 420 – 450 MHz Embedded COFDM Transceiver (DL435-30), Doodle Labs (SG) Pte. Ltd., Singapore,
<http://doodlelabs.com/products/sub-ghz-range/420-450-mhz-band-dl435.html>

[Earth] Google Earth, <http://www.google.com/earth/index.htm>

[hfs] Melina, Massimo (rejetto), HFS ~ Http File Server,
<http://www.rejetto.com/hfs/>

[HSMM-MESH] David Rivenburg, AD5OO, Robert Morgan, WB5AOH, Richard Kirchhoff, NG5V and Glenn Currie KD5MFW, HSMM-MESH™,
<http://www.hsmm-mesh.org/>

KB9MWR 1] Steve Lampereur, KB9MWR, Doodle Labs DL435-30 Reports, Advancing Ham Radio.. different ideas, January 29, 2012,
<http://kb9mwr.blogspot.com/2012/01/doodle-labs-dl435-30-reports.html>

[KB9MWR 2] Steve Lampereur, KB9MWR, [Ham-80211] Second 70cm source, ham-80211 -- TAPR Mailing List for Ham Radio Use of 802.11, February 27, 2012, <http://www.tapr.org/pipermail/ham-80211/2012-February/000649.html>

[M2 Yagi] 420-50-11 70 cm Yagi, M2 Antenna Systems, Inc., <http://www.m2inc.com/index.php?ax=amateur&pg=103>

[N0KEW] Kyle Whitney, N0KEW, quick test of the Doodle labs DL435-30, N0KEW, February 5, 2012, <http://n0kew.blogspot.com/>

[N9ZIA] Joseph Loritz, N9ZIA, Doodle Labs DL435-30 420-450 MHz OFDM Transceiver Experiments, <http://www.qsl.net/n9zia/dl435/index.html>

[microscope] Wayne Smith, WA4WZP, Webcam Microscope for the Radio Amateur, QST, ARRL, Newington, Connecticut, March 2012, page 38

[KD9LA] Fordham, David R., KD9LA, IEEE 802.11 Experiments in Virginia's Shenandoah Valley, QST, ARRL, Newington, Connecticut, July 1995, pp 35-41, <http://hsmm.wikispaces.com/file/detail/IEEE+802.11+Experiments+In+Virgini+Shenandoah+Valley.pdf>

[path loss] Path loss, Wikipedia, http://en.wikipedia.org/wiki/Path_loss

[pigtail] CA100 Pigtail Cable N Jack or Female Bulkhead to MMCX Male Right Angle (RA), 8 Inches (20.3 cm), <http://www.air802.com/product.php?productid=18505>

[POE 48] POE-48, Ubiquiti Networks, Inc., http://dl.ubnt.com/poe48_ds.pdf

[PSR] Packet Status Register, TAPR, <http://www.tapr.org/psr>

[standoff] Metal Standoffs with Screws (4-Pack), Model: 276-195, RadioShack Corp., <http://www.radioshack.com/product/index.jsp?productId=2102848>

[RS Pro] Ubiquiti RouterStation Pro, Ubiquiti Networks, Inc., <http://www.ubnt.com/rspro>

[reflash] TFTP flash, NewMedia-NET GmbH, http://www.dd-wrt.com/wiki/index.php/TFTP_flash

[The RFC] The RF Connection, <http://www.therfc.com/>

[tin box] Silver Rectangular Tins with Windows, The Container Store, Inc.,
<http://www.containerstore.com/shop?productId=10030959>

[W2LNX] Getting Started: Doodle Labs DL435-30 420 MHz Broadband Data Radios,
TAPR PSR #118 Spring 2012, <http://www.tapr.org/psr/psr118.pdf>

[Webcam] Logitech Pro 9000 PC Internet Camera Webcam with 8.0-Megapixel Video
Resolution and Carl Zeiss Lens Optics , Amazon.com, Inc.,
<http://www.amazon.com/gp/product/B000RZQZM0>

[Wistron] Wistron CM9 Atheros 802.11a/b/g miniPCI,
<http://www.mini-box.com/s.nl/it.A/id.387/.f>

[Xagyl] XAGYL XC420M 420-450MHz 1000mW miniPCI, Xagyl Communications, LLC,
http://www.xagyl.com/store_us/product.php?productid=31

[Yawcam] Magnus Lundvall, Yet Another WebCAM software,
<http://www.yawcam.com/>