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Source	Scott Marin SpectraPoint Wireless LLC 1125 E. Collins Blvd Richardson, Texas Voice: 972-852-7109 Fax: 972-852-6760 E-mail: smarin@spectrapoint.com
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Abstract	The FCC has established radio frequency spectrum allocations for LMDS in the USA. Within the assigned allocations, licensees are free to select bandplans and optimize channel plans to match local markets. When selecting bandplans, licensees must consider factors such as service mix, equipment capability, and interference. LMDS equipment manufacturers are responding with specific bandplan recommendations such as this one.
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Recommended LMDS Band Plan for Systems in the United States

Scott Marin, Doug Weiner, Jim McCoy

Bosch Telecom, Inc.
1125 E. Collins Blvd.
Richardson, Texas 75081
972-852-6700

Abstract — The FCC has established radio frequency spectrum allocations for LMDS in the USA. Within the assigned allocations, licensees are free to select bandplans and optimize channel plans to match local markets. When selecting bandplans, licensees must consider factors such as service mix, equipment capability, and interference. LMDS equipment manufacturers are responding with specific bandplan recommendations such as this one.

Index Terms — LMDS, Point-to-multipoint, fixed wireless access, bandplan, microwave radio.

1. Introduction

Regulatory agencies such as the U.S. Federal Communications Commission (FCC) are authorizing point-to-multipoint (PMP) radio systems to operate over a block of spectrum and throughout a large geographic area. Similar agencies in Canada, Australia, Argentina, and Japan are also authorizing systems. These systems are called either local multipoint distribution service (LMDS) or local multipoint communications system (LMCS), and operate in the bands around 28 GHz As an alternative or extension to copper or fiber networks, LMDS systems allow business and residential subscribers access to voice, video, and data networks. The licensing methods and policies differ from those for conventional point-to-point (P2P) radio systems which normally use channelized band plans and are authorized on a link-by-link basis.

The advantage of these open, flexible plans is that licensees are free to select the channel plan that best suits their local market, equipment capability, and business plan. Further, in a block-allocation scheme, licensees may ongoingly adjust channel plans to meet changing market conditions. A licensee may use equipment from a single supplier throughout a license area to minimize logistics cost and assure tight control on intra-system self-interference. Alternatively, equipment from different suppliers may be used in portions of the band to optimize delivery of specific services. Subscribers, licensees, and administrations all benefit from block spectrum and geographic area licensing of PMP systems. Regulatory agencies have less administrative burden, licensees have more freedom to provide what is needed in their area, and last but not least, subscribers have access to appropriate state-of-the-art services.

LMDS systems consist of hub sites located on tall buildings or towers and corresponding subscriber terminals located within a 360 degree area. LMDS transmitters at the hub sites have an approximate range of 5 km. To provide coverage for a geographic area such as a large city, several hub sites are used in a manner similar to cellular telephone systems. Subscriber terminals consist of small (12”) dish antennas that point toward the hub transmitters.

The frequency of each transmitter within the LMDS system is chosen using algorithms that optimize delivery of desired services. The chosen frequency must also maintain low levels of interference to receivers in other cells. Intra-system self-interference is a key constraint in the design and operation of these systems. Interference with systems in other licensing areas or which affects other radio services such as the fixed satellite service must also be considered when selecting frequencies, antennas, and transmitting power.

2. LMDS/LMCS Bands

The LMDS bands in the USA are shown in Figure 1 [1]. The bands are segmented into two blocks. Block A contains 1,150 MHz and block B contains 150 MHz.

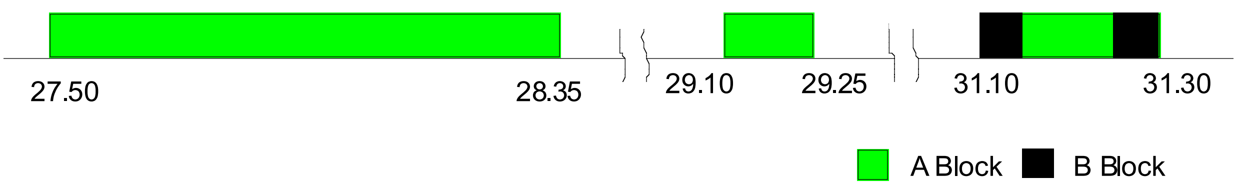

Figure 1, LMDS Bands in the United States

There are 493 license areas in the United States [2]. The license areas are called basic trading areas, or BTAs. The BTAs were determined by combining counties until the entire U.S. was covered. The size of the BTA was somewhat arbitrarily set to place each U.S. major metropolitan area into a different BTA.

The segments beginning at 27.5 and 31.0 GHz have a sole primary allocation and liberal restrictions on radiated power (+30 dBW/MHz for Hubs, +42 dBW/MHz for Subs). There are no restrictions on transmission direction between hub and subscriber (sub) stations.

The segment beginning at 29.1 GHz is shared with the mobile satellite service, MSS, [3] and has several restrictions that resulted from negotiated rule making [4]. The restrictions include: 1) subscriber stations may not transmit, 2) LMDS hub antennas are restricted as to upper elevation gain, 3) the aggregate radiated power per square kilometer is restricted, and 4) in some cases coordination is required with MSS earth stations. These restrictions limit the distance between hub and subscriber radios and increase system design and administration cost.

In all bands, coordination is required when transmitters are within 20 km of a BTA boundary. Within 20 km of a license boundary, signals from one system are likely to be detected as interference by receivers on the other side of the boundary. If the interference signal is strong enough, the system being interfered with may not be able to use a desired frequency. Frequency coordination is a process by which the two licensees agree to use certain frequencies and radiated power so both licensees maximize use of their band and the delivery of service to their customers. Rules for coordination between licensees across borders such U.S./Canada and U.S./Mexico are still being developed.

The currently licensed LMCS band in Canada is from 27.35 to 28.35 GHz (Figure 2). Additional spectrum from 25.35 to 27.35 GHz has been designated for LMCS use and will be auctioned after the current LMCS bands become heavily utilized.

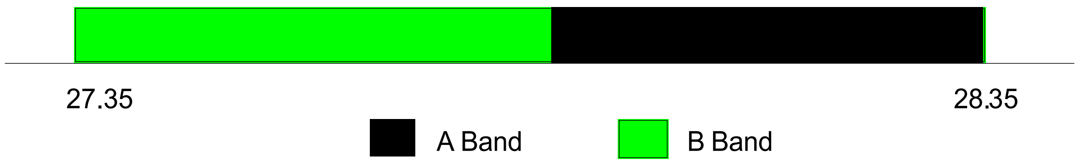

Figure 2, LMCS Bands in Canada

The frequencies from 25.25 to 27.5 GHz are shared with the inter-satellite service. Frequency sharing criteria for using P2P radios was completed by the Radio Communication Sector of the International Telecommunication Union (ITU-R) in 1997. The criteria are published in ITU-R Recommendation F.1249 which restricts radiated power for P2P systems to +24 dBW/MHz [5]. Sharing studies are underway by Joint Rapporteurs Group JRG7D-9D of the ITU-R to determine sharing criteria when using PMP systems.

Because of the large overlap between the Canadian and US bandplans, systems manufactured for the US market are also expected to be usable in Canada after appropriate certification. Because of the large Canadian market, radio system manufacturers consider commonality with Canadian bandplans necessary to reduce cost and expand the market for a specific system.

3. LMDS Band Planning

In the USA, an LMDS licensee is free to utilize allocated spectrum in a way that best addresses the local market. To efficiently utilize the spectrum, several factors must be considered in preparing a bandplan:

- Services mix (e.g. voice, video and/or data),
- One-way, asymmetric, or two-way service,
- Necessary transmit-to-receive frequency separation (transition band),
- Frequency coordination and interference with neighboring license areas or countries,
- Band sharing with other radio services,
- Radio architecture,
- Receiver sensitivity, (minimum Eb/No),
- Level of unwanted emissions received from systems providing other radio services or utilizing other bands,
- Level of unwanted emissions received from LMDS systems operating on adjacent channels or in different frequency blocks,
- Level of unwanted emissions produced by LMDS systems that fall inside and outside the assigned band,
- Pre-defined channel plan requirements, if applicable.

A commonly defined bandplan has technical and practical advantages along with some disadvantages. Among licensees, a commonly defined bandplan such as the placement of subscriber transmissions on one half of the band and hub transmissions on the other half of the band aids coordination and potentially allows full power transmissions closer to a coordination boundary. Services mix also comes into play, however. Voice services, and to some extent data services, tend to require symmetric bandwidth: the same amount of spectrum is used for upstream and downstream channels. Video services may be one-way (downstream) or highly asymmetric when a small upstream control channel is implemented. To support one-way service, hub transmitters and subscriber receivers must be capable of transmissions over the entire band. Similarly, to support symmetric services, subscriber terminals and hub receivers need only support transmission of half the band. Agreeing on which half of the band will be used for which type of service reduces the number of transmitter and receiver configurations a manufacturer must support, and this helps reduce cost.

Band planning can be done at various levels. At the highest level, it can be simple agreement on which half of the band is used for hub or subscriber transmissions and where transmit-to-receive transition bands are placed. At a more detailed level, upstream and downstream segments may be independently partitioned into channels, and the resolution for minimum channel spacing may be set. At a very detailed level, conventional channel arrangements can be stated that define channel bandwidth, bandwidth multiples, duplex spacing, and sometimes antenna polarization. Any plan must be designed carefully to avoid leaving spectrum unusable. Licensees must be allowed to deviate from a defined plan to address special markets.

4. PMP and P2P Channelization Considerations

Administrations typically have authorized P2P radio systems on a link-by-link basis using defined and fixed channel plans. Channel plans such as that described in ITU-R Recommendation F.746 [6], help organize the frequency bands so the regulatory agency can assign frequencies to radio systems without the likelihood of one system causing unacceptable interference in another system. The process goes something like this: a prospective licensee prepares an application requesting access to certain frequency channels. Administration officials confirm the feasibility of the link frequencies using coordination databases. If all is well, a station license is issued.

Administrations re-issue channels after reviewing geographic separation distance, unwanted emissions, and frequency separation requirements. For a P2P radio station, there is normally a one-to-one relationship between a station and a channel pair. Interference with P2P radios can come from several directions or several different stations. Because of the narrow beam antennas used at both ends of the link, interference may not be reciprocal. A station may receive interference from a source but not cause interference to the same source.

P2P radios are often used for trunking, and have identical data rates at both ends of the link. Data rates for trunking applications tend to match the defined data rates for the digital hierarchy, and also match the channel bandwidths assigned in the administration's channel plans.

The major disadvantages of authorizing links on a per-link basis are time and expense. Governments are notoriously slow in the authorization process, and this can hinder a provider's ability to respond to market demands. Additionally, overhead associated with the added personnel to administer the coordination can be a significant burden to government budgets.

PMP radio systems are quite different from P2P systems. PMP systems provide services to many subscriber terminals from a centrally located hub station. The hub station provides coverage over a geographic area, and to satisfy customer demand, typically operates simultaneously on several RF channels. In a large license area requiring several hubs for complete coverage, the licensee is self-motivated to re-use the spectrum in order to maximize the services delivered to customers. As long as the frequency block allocated is approximately 1 GHz, PMP systems provide competition to high-bandwidth wired alternatives that use coax or fiber. The flexibility to use a large block of spectrum in a way that matches local market demand results in the lowest possible cost to deliver services and the highest potential revenue from those services.

If there is a sudden change in the business mix within a particular area, a provider must be able to move quickly. Block bandplans greatly facilitate the process. Perhaps a large customer moves out of or into the area. The provider must be able to readily supply the greatest array of services priced competitively with other options available to the customer. This scenario is ideal for PMP LMDS systems. Block bandplans also allow great flexibility in the case of a market shift from symmetric services to asymmetric or one-way services. In such a case, a conventional symmetric bandplan may cause channels to go unused.

Much of the advantage afforded by LMDS PMP systems is the ability to compete with services imbedded into the local infrastructure. But imbedded providers are not sitting still for upstart competitors to glean the best and brightest accounts. They are as aware of the market and LMDS PMP advantages as their competition.

The optimum channel plans for PMP systems are also quite different from the plans used for P2P systems. PMP systems provide a multiplexing function in which service from several subscribers is aggregated into high-data-rate circuits to one or more networks at the hub. Unlike P2P stations, the hub operates on many frequencies, whereas at any instant of time, the subscriber terminal might transmit on only one. For some multiple access protocols, systems with high bandwidth downstream channels and low bandwidth upstream channels are the least costly to implement. This asymmetry between downstream and upstream channel bandwidth demands can cause frequency to go unused if a licensee must rigidly follow a symmetrically channelized frequency plan.

As mentioned, interference management is a key consideration and a fact of life in PMP system design. Interference may change dynamically as station transmissions and circuits within the links turn on or off and bandwidth assignment adapts to new calls. At times, a system may need to avoid certain frequencies because of excessive interference. Robust algorithms for dynamic frequency assignment that consider interference mitigation and algorithms for interference detection are likely to be deployed only after experience is gained operating PMP systems in a high-interference environment. Rather than constrain these algorithms to conventional channel plans which could result in more unusable channels, it seems better to remain flexible and allow development of optimum algorithms that maximize spectrum use.

5. Suggested Band Plan for LMDS Systems.

Based on the considerations listed above, the bandplan shown in Figure 3 is suggested as a plan that can support many LMDS market situations. For the large block A segment beginning at 27.5 GHz, the lower portion of the band is used for hub-to-sub transmissions, and the upper portion of the band is used for sub-to-hub transmissions. The choice of upper versus lower (hub versus sub) frequencies is now fairly arbitrary, but has its legacy in preliminary bandplans issued by the FCC during the LMDS rule-making process. The original bandplans were designed to avoid hub transmissions in certain portions of the band. As a result of band segmentation and negotiated rule-making, the arguments about subscriber or hub transmission placement are now moot points, but altering equipment to reverse the transmission sub-band requires substantial time and investment.

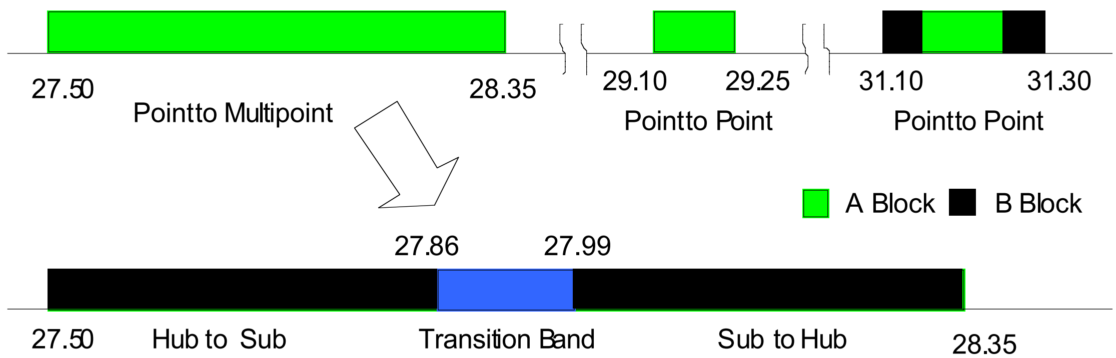

Figure 3, Suggested Bandplan for LMDS Systems in the United States

A transmit-to-receive transition band of nominally 130 MHz is necessary. Analysis has shown, however, that a transition band of only 120 MHz may be feasible with moderate risk of receiver desensitization.

Commonality with the Canadian LMCS band can be accomplished using P2P radios and by taking advantage of the transition band (Figure 4). The suggested bandplan also mitigates band sharing difficulties with the inter-satellite service below 27.5 GHz by using P2P radio systems.

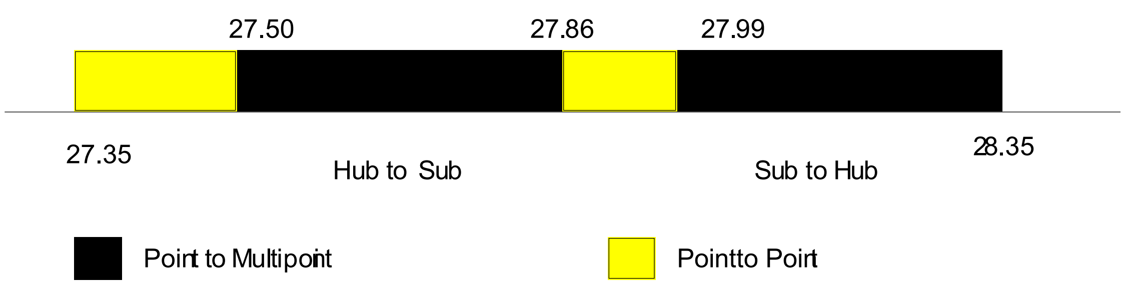

Figure 4, Suggested Bandplan for LMCS Systems in Canada.

For the small segments in block A, the 29.1 GHz segment is paired with the segment beginning at 31.75 GHz. To comply with Part 101 requirements, the 29.1 GHz segment is used for hub-to-sub transmissions. The 29.1 and 31.75 GHz segments are ideally suited for access links and point-to-point (P2P) backhaul links to node sites.

For block B, symmetric utilization pairing the lower and upper portions of the band is suggested. The lower portion is recommended for hub-to-sub transmissions and the upper portion for sub-to-hub transmissions. The block B segment is ideal for P2P links and could support point-to-multipoint (PMP) systems in a low-capacity deployment. The outstanding issue here is widespread international adoption of this plan. Such adoption would raise market demand and rationalize development of a unique product.

Channel plans within band segments depend significantly on service, traffic, and equipment characteristics. Telephony traffic such as T1/E1 tends toward paired carriers, and requires from 1 to 3 MHz of bandwidth. Digital video carriers tend toward satellite transponder formats on the order of 30 to 50 MHz. Systems highly optimized for asynchronous transfer mode (ATM) transport tend to use high bandwidth (30 to 50 MHz) hub-to-sub carriers and lower bandwidth (1 to 10 MHz) sub-to-hub carriers. Because of the wide range of channel bandwidths and independence between upstream and downstream bandwidths, detailed channel arrangements should remain unspecified.

The above bandplan is a high-level framework that can aid in frequency coordination. It can also allow systems between adjacent license boundaries to be more closely located or operate at higher power near the boundary. Some cost reduction may also occur through economies of scale since more equipment will be manufactured for a common plan than for multiple plans. At the intermediate level of a plan, planning parameters such as carrier center frequencies, if done on a fairly fine resolution such as 1 MHz, may aid development of synthesizers. But channel bandwidth and the pairing of upstream versus downstream channels needs to remain dynamically adjustable by the radio equipment to prevent wasting spectrum. At the detailed bandplanning level, spectrum would be wasted if rigid duplex spacing and only symmetric channel arrangement were invoked.

As another argument against detailed channel plans, note that adaptive frequency assignment algorithms are likely to evolve especially in the upstream path. The upstream path is a natural multiplexing function over the airway. Frequencies may be assigned on a per link, per call, per packet or per cell basis. Some frequencies may contain excessive interference (permanent or temporary) and might need to be tagged as unusable or usable only by certain subscriber stations that can overcome the interference without imbalancing the interference budgets elsewhere in the system.

6. Conclusions

The US LMDS policy intentionally delegates bandplan selection to the licensee so the licensee can optimize services for a specific market. The LMDS band is suitable for both point-to-point and point-to-multipoint systems and for delivery of voice, video, and data services. A common high-level bandplan, which designates the end of the band subscriber transmissions will occupy, aids coordination between licensees and with other radio services. A high-level bandplan can significantly reduce separation distance between systems. Detailed and inflexible bandplans such as those with defined duplex spacing and symmetric channel bandwidth may provide no incremental benefit over high-level plans and may result in unusable spectrum for many markets.

7. References

(1) United States Code of Federal Regulations, Title 47, “Part 101 – Fixed Microwave Services,” 10-1-97 Edition.
(2) Federal Communications Commission, “LMDS Bidders Information Package,” December 10, 1997.
(3) United States Code of Federal Regulations, Title 47, “Part 25 – Satellite Communications,” 10-1-97 Edition.
(4) Federal Communications Commission, “Report of the LMDS/FSS 28 GHz Band Negotiated Rulemaking Committee,” September 23, 1994.
(5) ITU-R Recommendation F.1249, “Maximum Equivalent Isotropically Radiated Power of Transmitting Stations in the Fixed Service Operating in the Frequency Band 25.25-27.5 GHz shared with the Inter-Satellite Service,” 1997.
(6) ITU-R Recommendation F.746, “Radio Frequency Channel Arrangements for Radio-Relay Systems,” 1997.