RESPONSE TO FCC NOTICE OF ENQUIRY:
USE OF SPECTRUM BANDS ABOVE 24GHZ FOR MOBILE RADIO SERVICES

DECEMBER 16, 2014

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1. Introduction

1.1. Background

The FCC Notice of Enquiry seeks to examine the potential use of spectrum above 24 GHz for the delivery and provisioning of 'advanced mobile radio services'. The FCC acknowledges that 5G standards are still being defined, and in the document, this the term '5G' is used as a short hand for next generation mobile services.

This document, issued by Bluwan SA, a provider of millimeter wave point to multipoint solutions in the 40.5 – 43.5 GHz bands[1], assesses the feasibility and practicality of commercializing non line of sight mobile radio technology in these bands, and clarifies alternative uses of this band. In general, Bluwan believes that commercialization of mobile radio access networks, and associated devices is not practical in the short term, and recommends allocation of these bands for the backhaul of heterogeneous networks, or fixed wireless access deployments in areas where the deployment of fiber optic last mile networks is economically or geo-demographically unachievable.

1.2. About Bluwan

Bluwan's carrier grade multi-gigabit wireless transmission technology allows service providers to increase the throughput and capacity of existing networks. Operating in the 40.5 – 43.5 GHz spectrum bands, Bluwan's technology can be deployed primarily for mobile backhaul and wide area broadband access applications.

Offering fiber-like speeds and capacity, its compact radio antennas allow service providers to deploy multimedia services at a fraction of the cost of deploying optical fiber, whether to individual cell sites or to customer premises.

Bluwan's solutions are the culmination of several years of R&D performed in collaboration with the Thales Group in the defence and aerospace markets. Bluwan is headquartered in Paris, France, with additional offices in London, and is a privately held company.

Bluwan's core technology and foundation was developed in the aerospace and defense industry, specifically at the heart of Thales Communication's advanced research and development labs.

The science team behind the development immediately believed that this technology could have civilian/carrier applications, and Thales invested in a dedicated R&D lab for Bluwan, spinned off as a separate company dedicated to the service provider vertical.

[1] Bluwan is also considering development of a 39 GHz based version of this solution for applicability in the US market, as this band has already been licensed to spectrum asset owners looking to deliver HetNet backhaul and fixed wireless access services through tier 1-3 service providers across the United States.

Bluwan started adapting the Thales engineering designs to function in ETSI harmonized, CEPT normalized frequencies in the 42 GHz band, specifically the 3 GHz of contiguous spectrum available between 40.5 – 43.5 GHz in the millimeter wave space (per CEPT). Components were demilitarized, equipments were de-ruggedized, and industrial supply chains were put in place to ensure carrier grade production and scalability.

During this R&D phase of our company's development, our solutions were tested by large operators, such as FT Orange, and this enabled Bluwan to iteratively develop LinkFusion, the industry's first point to multi-point *line of sight* multi-gigabit backhaul and access system, scalable to more than 10 Gbps per cell site, delivering hundreds of megabits per seconds to end customers and sites.

Bluwan is intrinsically focused on helping operators reduce their network TCO while facing the onslaught of demand in mobile and fixed broadband brought on by the massive proliferation of smart devices, the pervasiveness of cloud computing, and the rise of social.

Bluwan's LinkFusion technology from the ground up was designed to provide future proof capacity through its wide band radios, low latency performance due to its self-optimizing network architecture, and performance analytics.

Bluwan's ability to deliver fiber-fast connectivity wirelessly using a multipoint architecture allows us to enable next generation access and unleash the power of the future heterogeneous network. Operating in millimeter wave frequencies, and spreading the capacity provided by this rich, contiguous spectrum across multiple areas allows operators and ISPs to essentially deliver the equivalent of a Fiber GPON (gigabit passive optical network) connection to hundreds of cell sites or businesses from a single base station.

We use this ability to provide backhaul to dense or massively dense networks, or provide fast growth businesses with the fiber like speeds they need to scale their businesses (uncontended 100-250 Mbps per site).

2. General Response to Notice of Enquiry FCC 14-154

2.1. Challenges for the commercial deployment of Non-Line-of-Sight 5G services using mmWave[2]

Current industry understanding of 5G

5G technology requirements are a combination of two contradictory schools of thought : the first, an application led perspective with a seamless integration of 2-4G, Wi-fi and other technological advances that aim to provide 100% reliability and far greater coverage. The second, a step change in capacity/speed and end to end latency.

Based on current industry lab trials and discussions led by the NGMN, ITU, and the GSMA, the requirements can be summarized as the following:

- 1-10Gbps connections to end points in the field (i.e. not theoretical maximum)
- 1 millisecond end-to-end round trip delay (latency)
- 1000x bandwidth per unit area
- 10-100x number of connected devices
- (Perception of) 99.999% availability
- (Perception of) 100% coverage
- 90% reduction in network energy usage
- Up to ten year battery life for low power, machine-type devices

Backhaul Challenges

Despite the technological advances and lab trials initiated by operators (SK Telecom), and leading vendors (Nokia, Ericsson, and Samsung), it is at present physically impossible to envision a new technology enabled millimeter wave spectrum that could address all of the above requirements simultaneously.

The requirement for 1,000 times bandwidth per unit area can be serviced in the short to medium term by increased density of LTE roll-outs, upgrades to LTE-A, increased density of carrier Wi-fi (along with 802.11ac upgrades), point to point millimeter wave links, and the use of millimeter wave technologies to create multi-gigabit cells in point to multipoint line of sight configuration. Relays can handle line of sight issues and increase range of coverage. It is the combination of these technologies that will help achieve the required bandwidth density for a 2020 network.

These deployments will have massive implications for the OPEX on backhaul and power, as noted by key concerns from a survey of 89 operators simply on the challenges of deploying carrier wifi over the next few years. Over 40% of respondents stated backhaul and site issues

[2] This section primarily references the GSMA's latest report on 'Understanding 5G: Perspectives on future technological advancements in mobile', published on December 8, 2014 by the GSMA Intelligence Team.

as representing some of the biggest challenges in deploying Wi-fi access points over the next few years.

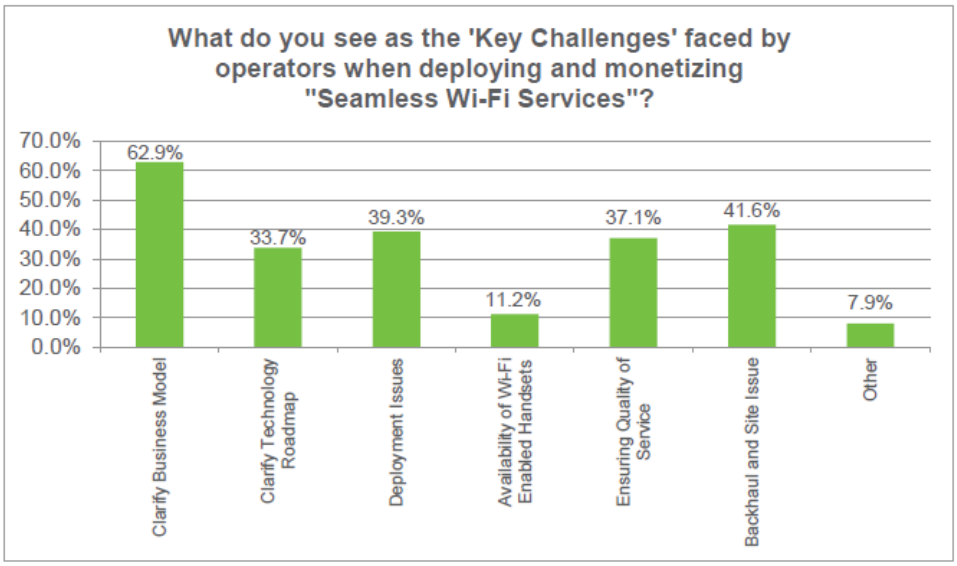


Figure 1 - Wireless Broadband Alliance, Maravedis Rethink Wireless, 2014

Meeting both of these requirements will have significant implications for OPEX on backhaul and power, since each cell or hotspot must be powered and all of the additional traffic being generated must be backhauled.

Practical near term commercialization of beam-forming technologies

As noted by the GSMA,

"While there are a number of spectrum bands which could potentially be used in meeting some of the 5G requirements identified to date, there is currently a substantial focus on higher frequency radio spectrum. As discussed in the Notice of Enquiry, operators, vendors and academia are combining efforts to explore technical solutions for 5G that could use frequencies above 24GHz and reportedly as high as 300 GHz. However, higher frequency bands offer smaller cell radiuses and so achieving widespread coverage using a traditional network topology model would be challenging."

Cell radiuses of 100m-200m will create a massive impediment for pervasive roll out, and will have a dramatic impact on operator business models.

The GSMA further notes that:

"It is widely accepted that 'beam-forming' - the focussing of the radio interface into a beam which will be usable over greater distances – is an important part of any radio interface definition that would use 6GHz or higher spectrum bands. This however means that the beam must be directed at the end user device that is being connected. Since the service being

offered is still differentiated from fixed line connections on the basis of 'mobility', the beam itself will have to track the device."

This is innovation that could make 5G an expensive technology to deploy on large scale, since each cell may have to support several hundred individual beams at any one time and track the end users that are connected via these beams in three dimensional space.

High-order MIMO (Multi-Input, Multi-Output) impact on existing topologies

High-order MIMO (Multi-Input, Multi-Output) is another method for increasing bandwidth that is often discussed. This is where an array of antennae is installed in a device and multiple radio connections are established between a device and a cell. However, high-order MIMO can have issues with radio interference, so technology is required to help mitigate this problem. This tends to focus on a need for the radio network to adjust its beam to take into account the specific orientation of the antenna at any given time.

The use of bands higher than 6GHz will likely require operators to invest in an entirely new RAN since it will have fundamentally different masthead requirements. Given the level of infrastructure required to achieve the desired network topology, operators may be forced to rethink their existing business models. New technology is rarely a cheap option, and the nature of the new technology that is required in the radio network makes it very power-intensive, hence counter to the stated requirement for significant reduction in overall network power consumption.

Sub-millisecond latency and impact on roaming and content caching

Latency is a primarily a function of processing in modems, switches and routers. Software defined networks, and network function virtualization, and equipment advances will lead to inevitable progress in processor speeds and network latency between now and 2020, however some argue that the speeds at which signals can travel through the air and light can travel along a fiber are governed by fundamental laws of physics. Subsequently services requiring a delay time of less than 1 millisecond must have all of their content served from a physical position very close to the user's device.

Due to the combined capacity and latency requirement, industry estimates suggest that this distance may be less than 1 kilometre, which means that any service requiring such a low latency will have to be served using content located very close to the customer, possibly at the base of every cell, including the many small cells that are predicted to be fundamental to meeting densification requirements. This will likely require a substantial uplift in CAPEX spent on infrastructure for content distribution and servers.

In the most extreme case, it would make sense for a single network infrastructure to be implemented, which would be utilised by all operators. This would mean all customers could be served by a single content source, with all interaction and interconnect with localised context also being served from that point at the base station.

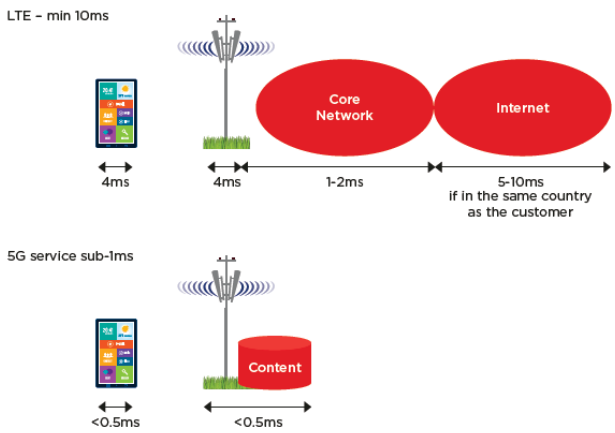


Figure 2 – Latency performance for LTE compared to latency requirement for 5G (GSMA 2014)

This would also imply that only one radio network would be built, and then shared by all operators. The implications on inter-country roaming would also be extremely complex to coordinate.

2.2. Alternative (and preferred) use for 39-42 GHz spectrum

HetNet Backhaul

Bluwan believes that 42GHz and its limited range and high bandwidth (and re-use factor) is perfectly positioned to meet the challenges of 5G Heterogeneous Network deployments, specifically for the backhaul of these HetNets. Bluwan considers that the FCC original plans for area licensing would be of great benefit to operators in speeding deployment of high capacity mobile broadband within urban areas. Bluwan would also like the FCC to consider management of this spectrum in block allocation and not in specific channel widths, as is being suggested by the FWCC. It would also be of benefit not limiting deployment to point to point links but also allowing point to multi-point technology, limiting urban skyline pollution, and increasing network Capex and Opex efficiency.

Operators and Regulators are licensing this spectrum in such a way as to maximise the potential use as well as limiting their exposure to having to rewrite the spectrum management tools and finally, limiting their risk to interference management.

In the European Union alone, and based on our modelling of the cost savings achievable through the adoption of PTMP 42 GHz backhaul for MNO base stations and on the assumption that these cost savings will be passed through to consumers in reduced prices for mobile broadband services, economic analysis shows that consumer surplus across the EU could amount to as much as Euro 1.5Bn over the next 10 years. Similar benefits could be expected for the United States of America.

Furthermore, this technology has practical uses for the deployment of enterprise access services in a fixed wireless environment.

Enterprise Fixed Wireless Access

Mobile Operators and Internet Service Providers typically add mmWave PTMP solutions to the network mix when they're struggling with increasing site rental costs, or when it's taking too much time to negotiate antenna space on a building or a tower. For example, one prospective customer had to pay nearly 20,000 $ a year for nine antenna slots in a central urban location. Previously, they would only have been able to connect nine customers. Furthermore, each time they needed to connect a customer, they would have to deploy two teams, one on each side of the link to get the client connected.

Because millimeter wave PTP uses very narrow beamwidth antennas (1 degree), alignment takes time, requires stronger mounting infrastructure on the customer end, and is generally more challenging to maintain.

With millimeter wave PTMP solutions, a service provider can easily connect 120 customers from that location with only 6 radio antennas, save on site rental costs, and increase total revenue and market share with a much faster time to market. Once the provider lights up a sector, they only need a technician on the client end to point back towards the sector. Bluwan's antennas are much easier to align (6 degree beamwidth). Operators can save on technician time and team size.

Finally, let's talk about scalability. As an ISP subscriber base increases, or bandwidth requirements increase, they can easily expand their capacity without any outdoor intervention. Bluwan's sectors start off at 600 Mbps capacity, but can scale to 1 Gbps, and ultimately all the way up 2.5 Gbps. That means that even with just 4 sectors, you could achieve up to 10 Gbps of on air capacity. If the operator were providing 100 Mbps service with a very advantageous 1:4 contention ratio on their network, this would mean 320 customers connected with only 4 outdoor units. The OPEX savings on this are significant. For example, 320 customers delivered on Point to Point links would require ~640,000$ per year assuming a cost of $2000 per year per antenna on a point of presence. An initial deployment of Bluwan's LinkFusion using 4 sectors could provide a saving of 98% on site rental costs alone.

Finally, we often find that a number of providers are effectively wasting the capacity of their Point to Point millimeter wave links by using them for medium bandwidth client requirements, e.g. 50-100 Mbps service. The ideal combination is to use Point to Point millimeter wave for very high bandwidth requirements, e.g., to a large enterprise, bank, or hotel, and use LinkFusion for small medium enterprises, where the requirements are equivalent to fiber to the curb, ADSL2+, or leased lines.

3. Proposed Licensing Scheme for 42 GHz spectrum

3.1. Spectrum Overview

Spectrum is a scarce resource and must be used efficiently and appropriately i.e. the right spectrum for the right application. In recent years the focus of regulators has been to release what is considered to be prime mobile spectrum i.e. below 3 GHz. However, there is limited amount of spectrum below 3 GHz where the MNOs have dominated spectrum ownership and have delivered mass market mobile voice and data services. Consequently the price of such spectrum is high and as demand for spectrum for services such as mobile data continues to rise, spectrum pricing below 3 GHz will remain high. Recently, regulators have started to assess innovative technologies such as cognitive radio which can utilise the "white spaces" or fragmented blocks between occupied bands of spectrum.

The broad market dynamics discussed in the Notice of Enquiry demand a solution which can deliver a fixed wireless high capacity services over appropriate spectrum bands. In summary, these market dynamics are:

- Increasing mobile data demand and consequent increasing demand for MNO backhaul
- Increasing and flexible capacity requirements by enterprises
- Universal Service Obligation for broadband in difficult to reach geographies

In the sections below we discuss how TDD PTMP based solutions utilising higher bands above 3 GHz are ideal for delivering high capacity, cost effective fixed solutions for MNO backhaul and enterprise and consumer access.

3.2. Why Wide Channels?

In 1948, Claude Shannon, an American mathematician and engineer, whilst working at Bell Labs published a landmark book (*A Mathematical Theory of Communication*) which laid the foundations of modern information and communications theory. Shannon asserted that the amount of error-free data that could be transmitted over a channel of any given bandwidth was limited by noise. While increasingly efficient technologies can be developed, there is a ceiling at which any gains of capacity are cancelled out by noise. This fundamental limit has become known as Shannon's Law.

Shannon's Law is particularly pertinent in the wireless world where spectrum is scarce. Engineering innovations have constantly pushed the limits of what can be delivered in terms of bits per second per Hertz (i.e. the amount of information in any given unit of spectrum), by decreasing noise in the channel.

Today modern radio technology is reaching the spectral efficiency limits set by Shannon's Law and as a consequence one of the key ways forward beyond engineering solutions like smart

antenna technologies, for the delivery of high capacity, is the harnessing of wider spectrum channels. Hence, two ways to increase capacity are more bandwidth (wider spectrum channels) and spatial selectivity.

However, to find clear blocks of spectrum that can support wide channels is a challenge for regulators and consequently for operators. Spectrum below 3 GHz has the range and penetration capabilities (i.e. through walls) which is ideal for mass consumer services and therefore such spectrum is highly prized by MNOs and TV broadcasters as well as for use with unlicensed technologies such as Wi-Fi in the ISM 2.4 GHz bands.

There is an emerging picture of spectrum release and availability at bands such as 39 GHz and 42 GHz. The ITU WRC 2007 designates the 40.5-43.5 GHz bands to fixed wireless services (i.e. PTP and PTMP) on a co-primary[3] basis. An increasing number of national regulators have adopted such recommendations as part of their national frequency plans e.g. Bahrain, Jordan and Saudi Arabia.

Ofcom, the UK's converged telecoms and media regulator, has been at the vanguard of releasing large blocks of spectrum for commercial use and as such set a precedence for the release of substantial blocks of 42 GHz through auction in 2008.

3.3. TDD vs FDD

Historically spectrum releases have adopted a band plan which facilitates Frequency Division Duplexing (FDD) as opposed to Time Division Duplex (TDD). In FDD systems uplink (UL) and downlink (DL) transmissions are allocated separate bands. The UL and DL are grouped in to contiguous blocks of paired channels as shown in Figure 3-2 and separated by a guard band.

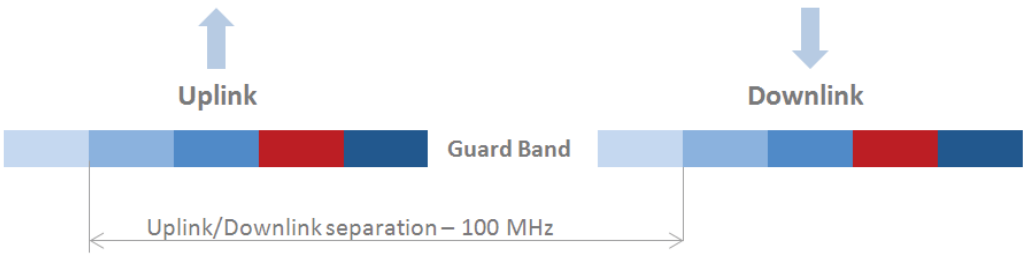


Figure 3 - FDD band plan showing uplink and downlink blocks separated by a guard band

The paired UL and DL channels are typically separated by a 100 MHz. This separation between UL and DL and the guard band minimises the interference of one FDD system and another.

FDD systems provide full duplex operation making them ideal for applications such as voice where UL and DL traffic is symmetrical. The large separation between UL and DL means that the interference between base stations or between subscriber units (e.g. handsets) is

[3] Co-primary means spectrum is shared between different types of application e.g. fixed wireless and satellite

minimised. This is particularly relevant for mobile systems where handsets move from one place to another and can be in close proximity with other handsets. The downside of FDD systems is that it can result in inefficient use of spectrum because of the requirement for a guard band. Moreover, FDD is inflexible for asymmetric data services in a data centric world where UL and DL bandwidth requirements are constantly changing and operators want the flexibility of dynamic provisioning to meet customer demands.

FDD systems also have a hardware disadvantage in that they require complex costly RF (Radio Frequency) filters to isolate the UL and DL channels. For fixed wireless data services i.e. non mobile systems, TDD has significant advantages over FDD. A TDD system does not require paired UL and DL channels and does not require a guard band. TDD systems use the same channel for UL and DL transmission separating them in the time domain as shown in Figure 4.

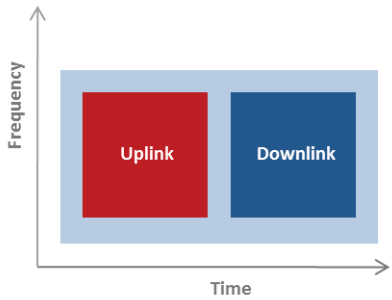


Figure 4 - TDD system where uplink and downlink operate in the same frequency block but are separated in time

TDD systems can flexibly allocate bandwidth for UL and DL depending on the service proposition requirements of the operator. Moreover, there is no requirement for complex RF filters to (effect separation between UL and DL) which can add significant cost to an operators' business case.

Issue	TDD	FDD
Need for guard band to separate UL and DL	No requirement	Required to separate UL from DL and is less efficient use of spectrum
Dynamic bandwidth allocation	Adaptive UL/DL allocation allows dynamic bandwidth allocation for UL and DL traffic	UL/DL allocation cannot be modified. This leads to unused spectrum for asymmetric operations and inflexibility in services that can be delivered
Need for RF filters	No requirement	Required to prevent interference across UL and DL channels
Hardware cost	Transmitter and receiver operate on the same frequency but at different times so hardware elements are reused and costs reduced	Hardware requires spatial separation and cannot be reused. This results in higher costs

Figure 5 - Summary of the benefits of TDD versus FDD

In summary (see Figure 5), TDD is the more desirable duplexing technology for data orientated fixed wireless services allowing operators to maximise their investment in spectrum and telecom equipment, while meeting the needs of individual customers.

3.4. The Advantages of a Dynamic TDD Point to Multipoint Solution

We discussed earlier that the efficient way to deliver high capacity fixed wireless data services is to deploy large blocks of contiguous spectrum and that such blocks of spectrum are increasingly available at cost effective price points at higher bands such as 39 GHz and 42 GHz. We then discussed why TDD can be the best way to leverage such wide blocks of spectrum to deliver high capacity fixed wireless data services.

In the next section we discuss why using a PTMP architecture can effectively harness wide TDD channels and provide operators with the optimal business case by:

- Efficiently managing scarce spectrum resources
- Dynamic allocation of capacity amongst subscribers
- Providing a flexible network architecture which lends itself to rapid subscriber acquisition

4. A Comparison of PTMP and PTP solutions

In the previous sections we discussed how operators can deliver high capacity fixed wireless data services using wide channel TDD spectrum at higher bands such as 39 and 42 GHz. In this section, we discuss how such TDD systems are deployed in a PTMP architecture to achieve the optimal business case for operators.

4.1. An Example Network

Consider a hypothetical network as shown in Figure 6, where a Point of Presence (PoP) connected to a backbone feeds *n* endpoints via a wireless PTMP or a PTP architecture. In a PTP architecture, *n* endpoints require n times dedicated PTP link. Compare this to a PTMP architecture which can service *n* endpoints via a central PTMP base station and lower cost subscriber units at the endpoints.

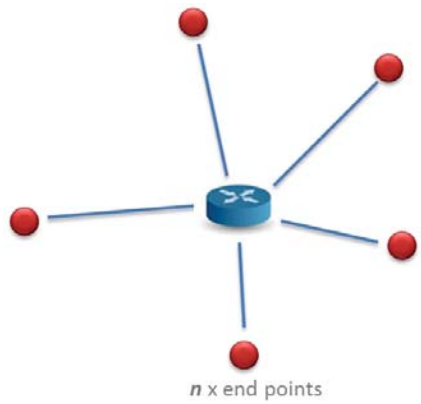


Figure 6 - A hypothetical network with n endpoints being serviced from a central Point of Presence

As a consequence of not requiring dedicated *n* links to serve *n* endpoints, a PTMP architecture can efficiently manage scarce spectrum resources as it can dynamically allocate capacity amongst *n* endpoints. This provides for a flexible network topology which lends itself to subscriber adds, moves and changes thus lowering OPEX for an operator and facilitating rapid subscriber acquisition. In the next section, we use this hypothetical network to assess the comparative CAPEX and OPEX.

4.2. CAPEX and OPEX drivers

Let's consider each of the major CAPEX and OPEX drivers for an operator looking to deliver high capacity fixed data services using PTMP and PTP systems. Our analysis refers back to the hypothetical network in Figure 6.

Radio masthead and subscriber unit costs

A traditional PTP microwave architecture requires large antenna dishes at each end of a link. Hence, in the network example of Figure 6, a PTP system would require 2*n* radio mastheads.

In a PTMP solution, on other hand, the central PTMP base station serves simpler and less costly subscriber units which are placed at the endpoints. Hence:

(2*n* x PTP radio mast head) cost > (PTMP base station + *n* x subscriber units) cost

Installation costs

Installing radio mast heads is costly and a PTP solution requires 2n radio masts as compared to a PTMP solution which requires a single base station and simpler subscriber units at the endpoints.

Planning applications

Visual impact has become a sensitive subject and putting up large numbers of radio antenna dishes is not acceptable in many environments. Traditional PTP solutions require dedicated radio mast heads at each end of a radio link. In certain geographies this can require a planning application for each radio mast head, which is not only a costly exercise but also time consuming. A PTMP solution with simpler subscriber units simplifies and reduces the cost of the planning process.

Site rental

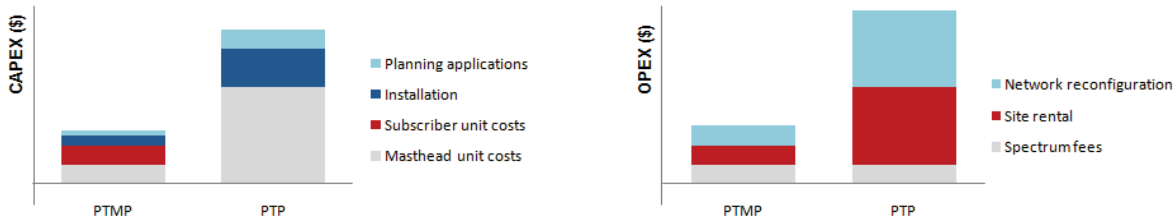
Tower operators and owners of prime real estate have benefited from the success of mobile voice and data and increasing site rental costs have become significant OPEX element of an operators' business case. With simpler subscriber units, a PTMP solution can significantly reduce site rental costs compared with PTP architectures.

Spectrum fees

A PTMP architecture can efficiently manage scarce spectrum resources as it can dynamically allocate capacity amongst *n* endpoints. With PTP, an operator is forced to dedicate spectrum to each link which can be inflexible and can typically be more expensive in terms of spectrum fees as you may pay for spectrum on a per link basis. In our comparison of PTMP and PTP CAPEX and OPEX in the next section, for simplicity we have assumed spectrum fees are identical for the two cases.

4.3. A comparison of PTMP and PTP CAPEX and OPEX

In Figure 7, we present a macro level view of the CAPEX and OPEX for PTMP and PTP architectures based on the hypothetical network in Figure 6. The comparison is simplistic but it helps clarify the key cost drivers and how a PTMP solution can be a more cost-effective solution for operators looking to deliver high capacity fixed wireless data services at a low TCO. A PTMP solution when combined with large blocks of contiguous TDD spectrum available at higher bands such as 39 GHz and 42 GHz, can deliver a cost effective, flexible and high capacity wireless solution. In section 5 we introduce Bluwan's LinkFusion PTMP solution for access and backhaul applications.



Notes:

- We have assumed that a PTP solution requires masthead units at each end of a radio link whilst a PTMP solution uses a simpler subscriber unit at the subscriber end
- For simplicity masthead unit costs are identical for PTMP and PTP
- Subscriber unit cost for a PTMP solution is 20% of a masthead unit cost
- Installation cost for PTMP is 25% of PTP for the example network
- Planning application costs for PTMP is 25% of PTP for the example network
- For simplicity spectrum fees are identical for PTMP and PTP
- Site rental and network reconfiguration for PTMP are 25% of PTP for the example network

Figure 7 - High level comparison of CAPEX and OPEX for PTMP and PTP architectures

5. Key Operator Requirements and Bluwan's LinkFusion

In previous sections we discussed the market challenges faced by two different operator categories:

- B2B operator delivering high capacity data services to enterprise customers
- MNOs requiring cost-effective high capacity backhaul to 3G/3.5G/4G/Carrier Wi-Fi base stations

On the face of it these operators have very different business models. However, there are some key common requirements across each of these operator categories. In the sections below we firstly examine how different technologies (including TDD PTMP) compare with regard to the key operator requirements and then we introduce the Bluwan TDD PTMP architecture.

5.1. Comparing TDD PTMP with other solutions

The key common requirements that run across our operator categories are the need for:

- High data capacity
- Flexibility in uplink and downlink i.e. support of asymmetrical and symmetrical services
- Support for IP and Ethernet with low jitter and latency
- Support for voice, video and data services
- Ease of network reconfiguration facilitating network adds, moves and changes
- Rapid provisioning of new services
- Rapid customer acquisition
- Low TCO in terms of CAPEX and OPEX that enables operators to build a robust business case and maximises the revenue per bit whilst minimising the cost per bit

We previously looked at how high capacity data services can be delivered using fixed wireless TDD PTMP solutions harnessing large contiguous spectrum blocks at higher bands such as 39 GHz and 42 GHz. In Figure 8 below, we compare such a fixed wireless TDD PTMP solutions with xDSL, Microwave PTP, Fiber and Leased Lines in terms of the key common requirements listed above.

Operator requirements	xDSL	Microwave PTP	Fibre	Leased Line	FTTA TDD PTMP
High data capacity	◔	◐	●	◕	●
Flexibility in uplink and downlink	○	●	●	●	●
Support for IP and Ethernet	●	●	●	●	●
Support for voice, video and data	●	●	●	●	●
Rapid provisioning of new services	●	●	●	●	●
Easy adds, moves & changes	○	○	○	○	●
Rapid customer acquisition	○	○	○	○	●
Low TCO	◑	◑	○	◑	●

Figure 8 - Benchmarking TDD PTMP wireless versus other technologies

5.2. LinkFusion: The Bluwan TDD Wide-Band PTMP solution

From Figure 8 we can conclude that a TDD PTMP wireless based technology has certain key advantages over rival technologies when it comes to delivering flexible, high capacity and low TCO data services. LinkFusion is Bluwan's multi-gigabit wireless network technology based on TDD PTMP technology at 42 GHz, and soon 39 GHz. The LinkFusion architecture is easily extendable using relay nodes and harnesses the cost-effective large contiguous spectrum blocks available at higher frequencies which we discussed in the previous chapter. LinkFusion's use of low power transmitters and high directivity antennas enable a high degree of frequency reuse, delivering very large amounts of capacity in a given area. LinkFusion's architecture makes it ideal for solving the challenges faced by our two operator cases.

LinkFusion for B2B operators

LinkFusion is compact and easy to deploy using a PTMP topology which enables operators to rapidly deploy and deliver flexible uplink and downlink high capacity data services. LinkFusion can deliver gigabit speeds using IP and Ethernet interfaces comparable to fiber but at a much lower cost and without the time and disruption required for laying fiber.

LinkFusion for MNO backhaul

LinkFusion provides a robust backhaul solution for MNOs integrating seamlessly with 3G, HSPA, Wi-Fi, Small Cells and LTE base stations. LinkFusion links multiple base station to provide a vastly superior download capacity when compared to legacy PTP microwave, allowing MNOs

to address increasing mobile data consumption and supporting multimedia applications such as video streaming.

LinkFusion is more compact, easier to deploy (because of its PTMP architecture) and as we discussed in the previous chapter, more cost effective in terms of CAPEX and OPEX when compared to traditional PTP microwave solutions.

5.3. Overview of LinkFusion architecture

The LinkFusion solution is a hierarchical, PTMP multi gigabit wireless wide area network. The solution is architected as a distribution tree connecting a service provider's PoP to relay nodes and ultimately reaching:

- Subscriber terminals (enterprise)
- Grouped terminals (such as those found on top of MDUs)
- Mobile base stations (for MNO backhaul)

From the PoP, each LinkFusion area served is supported by ultra wide band radios configured for PTMP. These areas are served by a spectrum bandwidth ranging from 250 MHz to 1 GHz (in the 42 GHz band, and soon 39 GHz) depending on the operator's spectrum licence. These wide band radios can transport a multiplex of waveforms which are adapted to the services and capacity required for the operator's customers. A diverse set of integrated antennas provided by Bluwan is leveraged to deploy a network tailored to the topology of the area. Typical link capacity is up to 250 Mbps which can either be dedicated to MNO backhaul or shared in the case of access solutions for enterprises. LinkFusion uses standard Gigabit Ethernet interfaces which are seamlessly integrated to an operator's existing network and services. Adding a LinkFusion solution to an operator's network improves capacity and throughput without requiring a change to existing services. LinkFusion is fully modular and can increase capacity and coverage as the operator's needs evolve.

In summary:

- LinkFusion can deliver high capacity data services by harnessing large blocks of cost effective TDD spectrum in ultra wide channels available at higher bands such as 39 GHz and 42 GHz
- LinkFusion offers a highly flexible PTMP network topology which can rapidly adapt to an operator's coverage and capacity requirements
- The cost of LinkFusion is significantly less than laying fiber and compared to a consumer Fiber to the Premises (FTTP) proposition can offer a per subscriber cost saving of up to 10x
- The LinkFusion PTMP architecture offers a modular solution that can scale with an operator's requirements as well as being more cost effective than a PTP solution in terms of both CAPEX and OPEX

5.4. Futures

Bluwan is currently involved in a number of research projects and trials for multi-beam antenna technology, radio over fiber, and advanced antenna design.

Through European partnerships, our company is focused on the development low profile, high gain and programmable multi-beam 40 GHz antennas, as well as the development of miniaturised radio modules that will enable operators to capitalize on the massive bandwidth available in the 40 GHz band, for future wireless backhaul and last mile access to bridge the digital divide in the most cost-efficient, easily deployable, and energy efficient way. More information on this can be found here:

http://issuu.com/themobilenetwork/docs/tmn_mag_issue_3_-_lr/c/slt5djb

(The Mobile Network, Issue 3, November 2013)

6. Response to Specific Questions

6.1. Question 31

Most 5G proposals or demonstrations using spectrum above 24 GHz are based on Time-Division Duplexing (TDD), whereas most 3G/4G systems are currently designed based on Frequency-Division Duplexing (FDD). Are there any inherent advantages of using TDD in higher frequency bands as compared to FDD? We seek comment on whether developers of 5G services are considering new technologies such as "Any Division Duplexing" (ADD), which proposes the possibility of using self-interference cancellation techniques. In light of the advantages of a flexible use policy, it would appear to be appropriate to allow licensees to choose their methods of duplexing for mobile wireless use in higher frequency bands. We seek comment on this issue.

Please refer to section 3.3 and 3.4 of this document. We are not considering ADD at this present time.

6.2. Question 34

We also seek comment on the specifications for data throughput, latency and other performance metrics that would be associated with advanced mobile services in the mmW bands. At least one source suggests that 5G would provide data rates up to 10 Gbps maximum and at least 100 Mbps at cell edges, with latencies of less than 1 millisecond.46 We ask whether these are reasonable expectations for the performance of advanced mobile services in these bands. If so, how will access to these types of data rates affect businesses and consumers? Would such capabilities create opportunities for new applications that do not exist today ?

Please refer to section 2.1 "Current industry understanding of 5G" of this document. The expectations are currently not commercializable in the next five coming years, and can have a major impact on existing investments on 4G LTE RAN deployments, which are still subject to major improvements (beam forming, interference management, massive MIMO, small cells, LTE-A).

6.3. Question 40

The Commission has applied various approaches to establishing technical rules for services operating above 24 GHz. There are two approaches that are particularly relevant here. For point-to-point services, the Commission's rules specify detailed technical requirements including specific channel plans, bandwidth limits, tolerance, emission limits, out-of-band emission (OOBE) limits, maximum transmitter power and/or EIRP, minimum antenna gains, and requirements for channel loading. In contrast, in services such as LMDS and 39 GHz, which have been licensed, by auction, on a geographic area basis, licensees have a great deal of flexibility in deciding how to deploy their equipment and services, subject to basic limits on power or requirements to coordinate with other licensees near the borders of their

service areas. Given that the technology is still in the early stage of development, we recognize that it is premature to seek comment on detailed technical rules at this time. We believe that certain technical parameters are more universally applicable regardless of the technologies and regulatory environment. We therefore seek comment on certain technical parameters, which will help us develop the general outlines of technical rules that we could adopt for mobile and other services in the bands above 24 GHz. In addition to the specific issues discussed below, we seek general comment on any other technical requirements we should consider within our rules, including any information about new technologies that will facilitate the assessment.

For 42 GHz, we would like the Commission to consider service and technology neutral allocation of wide-band (at least 250 MHz) frequency blocks on a geographical basis, considering the high degree of frequency re-use in this band, similar to the allocation that was made for 39 GHz spectrum, as discussed in section 5.1 and 5.3. This allocation should allow for Point to Multipoint applications.

6.4. Question 44

We recognize that some parties may contemplate uses other than mobile services for the mmW bands. In some of these bands, incumbent licensees currently offer fixed (including point-to multipoint) services. In addition, other parties may contemplate that the mmW bands would be used for non-mobile services. We invite those parties to explain their current and proposed uses of the mmW bands. Those parties should explain whether their uses would be compatible with mobile services as well as existing incumbent operations. We also ask parties proposing service rules for mobile use to offer rules that would accommodate as wide a variety of services and uses as possible.

We firmly believe that the 42 GHz band should be reserved for HetNet backhaul and Fixed Wireless Access Applications. There are no use cases for NLOS based 42 GHz systems currently and for the foreseeable future. This frequency lends itself perfectly to mid-range (in excess of 1 mile) multi-gigabit capacity line of sight based applications, provided that the license is granted on a technology and service neutral basis (e.g. legal PTMP usage).

6.5. Question 45

We specifically inquire about the utility of the mmW bands for backhaul. The Commission also recognizes that availability of economical backhaul solutions for small cell deployment is a challenge in today's environment and expects it to continue to be a challenge for access point deployment in the future. We seek comment on the extent to which it is feasible to use bands above 24 GHz for backhaul, particularly non-line-of-sight (NLOS) backhaul, which may be necessary for dense cell deployments. Are there enabling technologies that will facilitate the shared use of bands for different types of uses? Could the 5G technologies discussed above also provide backhaul capabilities? Would it be possible to use "in band" service in which

backhaul reuses frequencies that are also used for access? Given the short ranges of developing 5G technologies, would mesh or multi-hop architectures be viable?

It is clear that the future of backhaul is evolving. Just as demand for macro-cell backhaul is decelerating, the need to provide high capacity, cost efficient, scalable and adaptable backhaul systems to cater for ever increasing bandwidth density requirements is becoming increasingly important. A multi-gigabit point to multipoint wireless transmission system allows service providers to solve the bandwidth density challenge by dramatically increasing the coverage and capacity of existing networks.

The technology developed by Bluwan is the culmination of several years of R&D performed in collaboration with the Thales Group in the defence and aerospace markets. Bluwan has developed the 2nd Generation of Carrier Grade Point to Multipoint (PTMP) microwave equipment in the 42GHz band to meet the capacity requirements for next generation networks in a PTMP configuration, ensuring substantial year-on-year Opex savings.

Bluwan's LinkFusion can scale to deliver multi gigabit sector capacity by combining up to 20 x 40 MHz channels into a single outdoor sector radio, thus delivering a sector capacity up to 2.5 Gbps, allowing operators to deliver 125 Mbps or 250 Mbps IP peak performance connectivity for multi-layered heterogeneous networks including 3G/4G macro sites, small cells, or carrier WiFi backhaul, as well as providing very high throughputs to high value triple play or enterprise customers on the same platform and maximising the ROI of the Hub site infrastructure cost.

Up to two channels can be dedicated to a Network Terminating Equipment (NTE), or a single channel can be shared across multiple NTEs for lower throughput requirements. For the first time, operators are able to deploy Multipoint Microwave technology and service peak PTP performance at a substantially lower Capex and Opex than FTTx solutions.

Bluwan's 42 GHz LinkFusion Millimetre Wave (mmW) Point-to-Multipoint backhaul system is ideally suited for HetNet backhaul. With 10 Gbps per 4 sector transmission hub[4], MNOs can easily address their bandwidth density requirements. For the first time, using Bluwan's compact 125 Mbps and 250 Mbps Network Terminating Equipment (NTE), MNOs can deliver peak Point to Point performance combined with the TCO benefits of a Point-to-Multipoint solution.

Bluwan's LinkFusion self-backhauling Relay node enables operators to overcome LoS (Line-of-Sight) hazards and easily deploy coverage to black-spots and street canyons. Beyond the traditional cost reduction associated with the usage of Point-to-Multipoint, Bluwan's LinkFusion system enables operators to simply light up a coverage area by deploying a capacity pool, and deploy end-points or relays as required to provide total coverage. Operators no longer need to spend large amounts of time designing and re-designing complex mesh or daisy-chained network topologies.

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[4] 6 sector hexagonal deployment is also available for dense frequency re-use

Due to LinkFusion's inherent high capacity and bandwidth pooling capabilities, backhaul service providers or MNOs engaged in network sharing alliances can deliver multi-dimensional QoS profiles for multiple operators across multiple sites, enabling them to easily assign bandwidth pools for backhaul and RAN sharing.

To summarize the possibilities opened up by 42 GHz availability:

- *PTMP Dynamic TDD System*
- *Operates in the licensed, uncongested and inexpensive 40.5 – 43.5 GHz Q-band spectrum*
- *10 Gbps scalable Hub Capacity*
- *16x the bandwidth of traditional PTMP*
- *Zero-touch provisioning & Self Optimising Network*
- *125 Mbps and 250 Mbps Peak Performance*
- *Dedicated bandwidth for high capacity multi-technology small cells, macro-sites, or enterprise*
- *Capacity sharing for lower bandwidth small cells, Wi-Fi Access Points, and small medium enterprises*

6.6. Question 50

In the discussion below, we invite comment on the suitability of the Local Multipoint Distribution Service (LMDS) bands, the 39 GHz band, the 37/42 GHz bands, the 60 GHz band, the 70/80 GHz bands, and the 24 GHz band for advanced mobile services. We also invite comment on any other bands above 24 GHz that are not included in this list but might be appropriate. We seek comment and discussion on bands above 95 GHz that commenters believe would be suitable candidates for mobile services. As with other bands, we encourage commenters to explain the characteristics that enable mobile services, the nature and extent of incumbent services, and steps that can be taken to ensure incumbent uses are protected.64 Our intent is to examine any mmW bands that could be suitable for advanced mobile services, whether or not the band is part of a global and organized standards effort for 5G. The following is a brief summary of the most salient characteristics of the relevant bands.

Our response is limited to the suitability of the 39 GHz and 42 GHz bands, which pertain to our area of expertise.

LMDS frequencies could be potential candidates for mobile services, though this has to be further investigated. Samsung has had some degree of success. Above Ka band, propagation, diffraction and reflections, trees and rain, would lead to costly electronics, power needs and its yield (even in the future SiGe or GaN) would result in an unacceptable power consumption level for handsets. As for mobile devices, very high and fast fluctuations of diagrams (antennas and reflections) is a non-solved problem. Lack of directivity on the mobile would reduce the sensitivity of the satellite receivers.

Current trials show effective demonstrations of 5G applications in the 28GHz. Given the lack of success of traditional LMDS in the United States, it is recommended to evaluate applicability of the 24-27 GHz and 28 GHz bands carefully. Such developments of 5G could deliver mobile services in the form of small cells with a range of 100-150m combined with very high capacity. This will require backhaul for massively dense networks. The 39 and 42 GHz bands are ideally suited for this application due to the wide spectrum and cost/effective propagation properties for line of sight based point to multipoint systems. Point to Point links in these bands will result in hundreds of microwave, fixed links, which will result in a much higher total cost of ownership for operators, and will also be very challenging to deploy (arrays of antennas on every major point of presence).

42GHz for 5G is much less efficient than in the Ka band as far as propagation and necessary reflections (rough surfaces, trees and rain). Current advances in technology cannot overcome physical limits: 1-noise factor is already @ 2db for the receivers and there is no foreseeable progress here; 2-one way or another, to compensate propagation losses and deliver more bandwidth, one would need more power and antenna processing. Together with MMIC yield (even with SiGe or GaN) we have here two reasons that will dramatically increase mobile devices power consumption (already a problem for handsets). For vehicles, motion will create a very high and fast modulation due to the complex diagrams of antennas and reflections (to be solved together with Döppler). Finally, because mobile devices will have no highly directive antenna, thousands of them would create a general noise to be studied particularly for the uplink satellite (military). Some work is being done to mitigate this with tracking as discussed earlier in section 2.1. As far as radio-astronomy, mobile services, and devices should not be deployed in the vicinity of radio-telescope.

We do not recommend allocation of the 42 GHz band for mobile services, but rather for point to multipoint wide band backhaul of such services developed in other bands operating in narrower channels (such as 28 GHz).

6.7. Question 61

We seek comment on the suitability of the 39 GHz band for advanced mobile services. As noted above, the Commission assumed that geographic area licensees would be in the best position to coordinate fixed and mobile uses in that band. Is that assumption still accurate, or are additional procedures or rules necessary? Also, in the 39 GHz Order, the Commission required that 39 GHz operators follow Part 101 Fixed Service rules to coordinate frequency use with operators in adjacent license areas, but it did not establish power-flux-density limits or other rules to govern interference between geographically adjacent licensees. As mentioned above, we generally find it necessary to establish such specified limits whenever we authorize the provision of mobile services by licensees holding exclusive GSA service rights. We invite comments on the need for such a requirement to accommodate the provision of advanced mobile services in the 39 GHz band. With respect to the FSS, do the existing limitations on satellite power flux density make such operations compatible with mobile

operations? What other technology characteristics should be taken into account to assess compatibility between potential commercial mobile broadband service with existing incumbent operations including federal MSS and FSS? Are there any additional measures needed in terms of OOBE limits that are needed to protect federal MSS and FSS downlink operations in the adjacent 40-40.5 GHz band? We also seek comment on whether any limitations or special rules on mobile use would be necessary in order to protect Federal military FSS use of the 39.5-40 GHz band.

See response to Question 50 regarding suitability for mobile services for the 39 GHz band.

Fixed and mobile services coexistence with geographical separation should not present a problem if cell edges are separated with more than 1 mile and if the systems comply with EN 301 997. Colocation on the same spectrum is not possible.

There won't be any interference with satellite FSS & military in the adjacent band (39.5-40.5) if spurious rules, as defined in EN 301.390, are applied on the 39GHz systems. This requires clean synthesisers, up converters and some filtering.

6.8. Question 65

Status of Mobile Allocation and Rights: There are co-primary allocations for terrestrial mobile service in these bands, but the Commission has not yet adopted service rules to authorize such services. All operations in the 42-42.5 GHz band are urged to take all practicable steps to protect radio astronomy observations in the 42.5-43.5 GHz band from interference.

Radio-Astronomy is not an issue, provided antenna directivity and distance from the telescope. Indeed the attenuation of distance, antennas directivity, creates a noise floor several tenths of db under radio-telescope sensitivity. CEPT has accepted the mitigation, possible under EN 301 997 conditions.

6.9. Question 67

In addition to Fixed and Mobile allocations, there is a co-primary FSS (space-to-Earth) allocation for the 37.5-38.6 GHz band segment, and Broadcasting and Broadcasting-Satellite Service (BSS) allocations for the 42-42.5 GHz band segment. The Commission has proposed eliminating the BSS allocations in the 42-42.5 GHz band and adding a FSS (space-to-Earth) allocation in order to protect adjacent channel radio astronomy in the 42.5-43.5 GHz band. As described above, the soft segmentation plan adopted in the V-Band Second Report and Order favors terrestrial services in the 37.0- 38.6 GHz band.

It is certainly a good decision. Satellite to Earth @ 42.5GHz would certainly fully blind earth radio-telescope on Earth. A Q band PTMP fixed system, as stated in Q-65 does not reduce radio-telescope sensitivity. Solutions related to the adjacent band are answered in Q-61. Now, for mobile services at 42 GHz, there is no antenna isolation from the mobile devices towards the radio telescope. Henc, in the vicinity, with a lot of devices, it could create a certain ambient

noise. It is more the mass of more or less isotropic radiations than the LOS or NLOS argument that should be fostered.

6.10. Question 69

We seek comment on the suitability of the 37 GHz and 42 GHz bands for advanced mobile services. Through the IRAC process, we will work with NTIA and the Federal agencies, to update the information on current and future Federal use of the 37 GHz band and establish sharing arrangements to promote the development of innovative commercial wireless services. Since we have not developed any terrestrial service rules for these bands, we seek comment on the appropriate licensing mechanism for those bands, as discussed below. With respect to the 42 GHz band, would authorizing mobile operations be consistent with protecting radio astronomy observations in the 42.5-43.5 GHz band? As an alternative, we seek comment on FWCC's proposal to authorize fixed point-to-point use of the 42-43.5 GHz band. Would fixed point-to-point use be more consistent with other uses in that band?

Again, we can refer to CEPT and ETSI: Q band PTMP can be mitigated with Satellite and does not reduce sensitivity of a distant radio-telescope.

Now, to use PTP instead of PTMP does not remove the potential problem, we even think it may be worse, indeed there will be as many links and µwave links that have higher EIRP than PTMP; thus, if one of the links is in the direction of the radio-telescope, the interference will be greater than that of a PTMP terminal or of a Transmission sector.

Important conclusions:

- *Q band is not suited for mobile: performances, power consumption for handsets and amplitude over modulation for vehicles*
- *Mobile Q band system will certainly reduce the sensitivity of a satellite on the same frequency band (jamming the uplink)*

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