International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R F.1498-1
(05/2002)

Deployment characteristics of fixed service systems in the band 37-40 GHz for use in sharing studies

F Series

Fixed service

International Telecommunication Union

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
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RECOMMENDATION ITU-R F.1498-1*

Deployment characteristics of fixed service systems in the band 37-40 GHz for use in sharing studies

(2000-2002)

Scope

This Recommendation provides deployment characteristics of fixed wireless systems for use in sharing studies, aimed at efficient spectrum utilization of the band 37-40 GHz to be utilized for high-density applications in the fixed service (HDFS). The Annex gives examples of high-density deployment situations of point-to-point systems used for links between mobile base stations and infrastructure networks as well as subscriber based point-to-point and point-to-multipoint networks that substitute for optical fibre subscriber access connections.

The ITU Radiocommunication Assembly,

considering

a) that the band 37-40 GHz is allocated to the fixed service (FS) on a primary basis;

b) that the telecommunication deregulation trend increases demand for competitive local access alternatives;

c) that point-to-point (P-P) FS systems are deployed on a large scale and their use is growing in the band 37-40 GHz;

d) that mobile network and competitive access infrastructures represent the major FS applications in this band;

e) that an increasing number of P-P and point-to-multipoint (P-MP) FS stations are deployed or being planned for local access use in the band 37-40 GHz;

f) that the high concentrations of service users in urban, suburban and industrial areas require high-density deployment of user terminals in these areas;

g) that propagation conditions in this band are predominantly controlled by rain attenuation;

h) that technological progress in system implementation and deployment are continually improving competitive local access service provisioning in this band;

j) that emerging applications in the high density fixed service (HDFS) systems such as broadband wireless access (BWA) may require availability objectives of at least 99.999% at 1×10^{-6} bit error rate (BER) threshold and nominal BERs of 1×10^{-11} under clear-sky conditions;

k) that in order to achieve such performance, link budgets may require coding gain such as forward error correction (FEC) coding gain;

l) that the band 37.5-40 GHz is also allocated on a primary basis to the fixed-satellite service (FSS) (space-to-Earth) and that an increasing number of FSS systems are being planned for this band;

* Radiocommunication Study Group 5 made editorial amendments to this Recommendation in 2009 in accordance with Resolution ITU-R 1.

recognizing

a) that fixed systems in the band 37-40 GHz include ubiquitous deployment of P-P and P-MP systems over specific service areas;

b) that administrations may authorize P-P and P-MP systems using discrete channelling or frequency block assignments; within a frequency block, it is common practice to permit a range of technologies, carrier frequency bandwidths and access techniques,

recommends

1 that efficient spectrum utilization and performance and availability, based on the applicable ITU-T and ITU-R Recommendations, be primary considerations for high-density deployment of systems in the FS in the band 37-40 GHz (see Note 1);

2 that the propagation conditions in this band be advantageously used in path engineering to achieve extensive frequency reuse;

3 that Annex 1 can be referred to for FS system deployment guidance in the band 37-40 GHz for use in sharing studies.

NOTE 1 – Relevant Recommendations are, *inter alia*:

ITU-T Recommendations

ITU-T Recommendation G.821 – Error performance of an international digital connection operating at a bit rate below the primary rate and forming part of an integrated services digital network.

ITU-T Recommendation G.826 – Error performance parameters and objectives for international constant bit rate digital paths at or above the primary rate.

ITU-T Recommendation G.827 – Availability parameters and objectives for path elements of international constant bit rate digital paths at or above the primary rate.

ITU-T Recommendation G.828 – Error performance parameters and objectives for international, constant bit rate synchronous digital paths.

ITU-R Recommendations

Recommendation ITU-R F.697 – Error performance and availability objectives for the local-grade portion at each end of an ISDN connection at a bit rate below the primary rate utilizing digital radio-relay systems.

Recommendation ITU-R F.1668 – Error performance objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections.

Recommendation ITU-R F.1565 – Performance degradation due to interference from other services sharing the same frequency bands on a co-primary basis with real digital fixed wireless systems used in the international and national portions of a 27 500 km hypothetical reference path at or above the primary rate.

Recommendation ITU-R SM.1046 – Definition of spectrum use and efficiency of a radio system.

Recommendation ITU-R SM.1271 – Efficient spectrum utilization using probabilistic methods.

Recommendation ITU-R F.755 – Point-to-multipoint systems used in the fixed service.

Recommendation ITU-R F.758 – Considerations in the development of criteria for sharing between the terrestrial fixed service and other services.

Recommendation ITU-R F.1102 – Characteristics of fixed wireless systems operating in frequency bands above about 17 GHz.

ANNEX 1

Fixed service deployment characteristics in the frequency band 37-40 GHz considered for use in sharing studies

1 Introduction

The progressing deployment of FS stations or FSS earth stations may affect the future expansion of either service in the same frequency band. Accordingly, the FS station deployment patterns and the FSS earth station deployment patterns required for the introduction and growth of viable services have a major impact on band sharing.

A combination of different propagation and service development conditions results in substantial FS deployment differences in the bands below 14 GHz where sharing between FS and GSO FSS systems is currently practised, and in the bands above 17 GHz which are being considered for additional sharing with space services, e.g. the FSS. Propagation conditions result in usable FS hop lengths that are inversely proportional to frequency. The bands below 8 GHz are therefore best suited for long-distance transmission, whereas the much shorter usable hops at frequencies above 17 GHz are particularly well suited for cellular infrastructures and local access applications which are rapidly growing in urban, suburban and industrial areas.

In the bands below 14 GHz, the predominant deployment patterns of both services facilitate sharing, because FS deployment along major communications routes results in branching network configurations that leave large geographical areas free for FSS gateway deployment. This facilitates realizing the interservice separation distances that are needed to limit interference to tolerable levels.

In the band 37-40 GHz, however, the predominant FS deployment pattern is characterized by mobile network infrastructures and direct subscriber access in local areas of high population density, concentrated industrial activity or campus settings, and FSS deployment patterns could include these areas as well. FSS earth station deployment outside areas of dense FS deployment should present few coordination problems. The same is not necessarily true with respect to the deployment of FSS earth stations within and adjacent to the FS deployment and area-wide FS licence areas, and vice versa.

The information on FS deployment, presented in this Annex, is intended to be used in the assessment of FS/FSS earth station sharing in the 38 GHz band.

2 Basic differentiation between conventional fixed wireless systems and BWA applications in the FS

FS deployment in the 38 GHz band started with conventional applications migrating upwards from lower frequency bands that are approaching saturation due to increasing deployment or new, more restrictive regulatory measures. The 38 GHz band was particularly attractive for the fast growing mobile infrastructure applications which account for the majority of conventional FS applications in this band. A favourable regulatory environment in many countries and progress in telecommunications deregulation stimulated a new type of deployment in this band, direct-to-user BWA, which substitutes for and competes with optical fibre access.

Although BWA deployment started by using the commercially available systems that have been developed for conventional P-P FS applications, the BWA deployment patterns and link designs are substantially different in several aspects. The fundamental difference is due to the different service needs. The deployment of conventional FS systems in the 38 GHz band instead of in a lower frequency band with more favourable propagation conditions became necessarily more restricted in usable link length, but fit very well to the requirements of GSM900/1800 systems in urban areas. Commercially available transmitters and receivers are designed for such applications based on trade-offs between high system gain, on the one hand, and low cost, low power consumption, low weight and small size, on the other. This makes it possible for conventional FS applications to satisfy, in a technically and economically viable manner, the substantial percentage of deployment requirements near the upper limit of usable link lengths in the 38 GHz band, which makes large fade margins more practical.

BWA deployment, by comparison, uses substantially smaller link lengths, and would be better served by P-P systems with substantially lower system gain. In fact, the transmitter power in most P-P BWA links is routinely set to or near the lowest adjustable level, which is necessitated by the stringent frequency reuse requirements in high-density cellular deployment. This requires operation with the lowest fade margins that assure the desired link availability. This applies also to the more recently introduced P-MP BWA systems that usually complement P-P deployment by providing service to the users that are closest to the cell hub. Nevertheless, P-MP system may not be able to serve those subscribers within their area of coverage that require higher data rates which can be provided with P-P systems. The shorter links and higher deployment densities of BWA systems result also in substantially higher elevation angles. These two distinctive characteristics of BWA systems make them more susceptible to interference from FSS systems than is the case with conventional FS systems. The net result is that, as far as band sharing capability is concerned, cellular BWA systems display great similarity to cellular mobile systems, due to the high densities and unpredictable locations of subscribers.

3 Representative examples of 38 GHz HDFS deployment

The initial large-scale deployment of P-P systems in the band 37-40 GHz was in mobile networks with a concentration mainly in and around urban and industrial areas. A more recent large-scale FS application in this band represents a new variety of fixed wireless access (FWA) using P-P links that terminate directly on subscriber premises.

3.1 Development of 38 GHz HDFS systems for mobile infrastructure applications

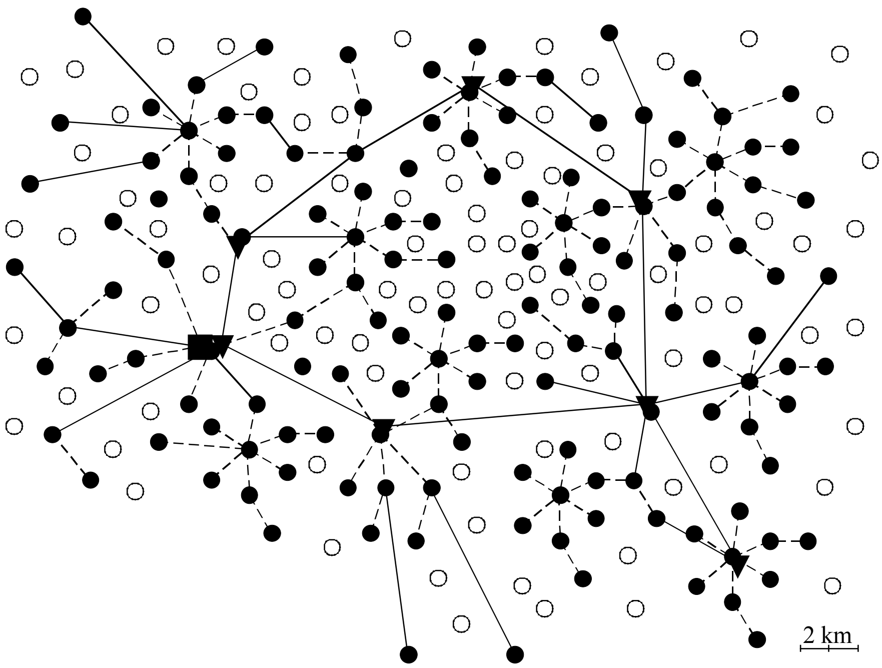
Figure 1 illustrates an example of the current primary application within a mobile network for 38 GHz deployment in urban areas where deployment densities have progressed into the range of 1 to 10 stations per km^2. The links are designed to satisfy availability criteria between 99.99% and 99.999%.

A large number of links in the 38 GHz band are deployed in several countries in Region 1. In Germany, for example, a total of some 11 200 P-P links had been deployed by the end of 2000. In Table 1 the development of the deployment is indicated.

It is anticipated that this number will increase significantly during the next years, with increasing FWA applications. It can also be noted that 80% of the links are concentrated in 15% of the total area (see Fig. 8). The other links are distributed over the remaining area, but there are also numerous areas with no or neglectable 38 GHz applications.

FIGURE 1

Illustrative application of 37-39.5 GHz P-P systems for mobile infrastructure (e.g. GSM1800) in dense urban areas



■ Mobile switching centre (MSC)

▼ Base station controller (BSC)

● Mobile base station

○ Future possible base station

——— Cable or hop in another microwave band

- - - - - Microwave hop in the 38 GHz band

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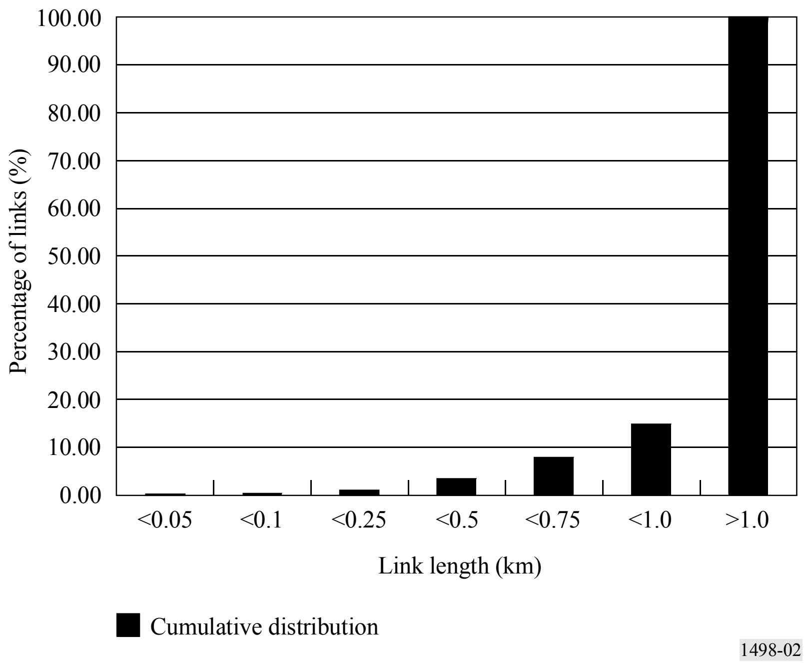
TABLE 1

Development of link deployments in the 38 GHz band in Germany

End of year	1994	1996	1998	2000
No. of links	243	1 867	6 346	11 174

FIGURE 2

Cumulative 38 GHz link length distribution statistics in Germany for mobile infrastructure networks



The corresponding distribution of elevation angles is presented in Fig. 3. Only 10 links are currently deployed with elevation angles higher than 25°. The following specific facts may be the main reasons that the elevation angle distribution will be significantly different compared to subscriber based HDFS networks in the United States of America in § 3.2:

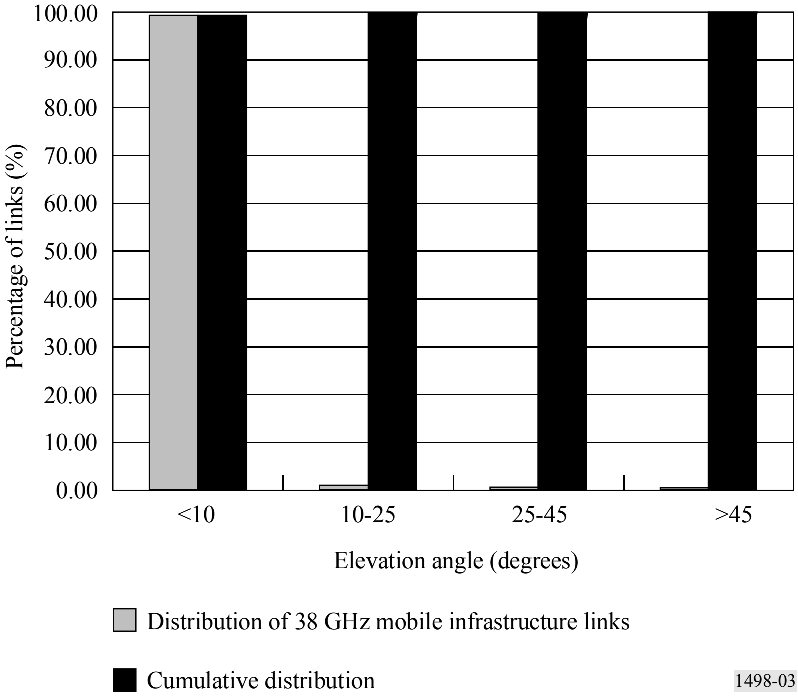
– the major number of links is above 1 km (in the range of 1-4 km);

– terminal heights in mobile infrastructure networks are more commonly distributed;

– and possibly architectonic differences in metropolitan areas in Germany and the United States of America.

FIGURE 3

38 GHz link elevation angle distribution statistics in Germany



3.2 Deployment of 38 GHz links in the United States of America for subscriber-based HDFS networks

Figure 4 illustrates, for one metropolitan area in the United States of America, a deployment of hub configurations providing various transmission capacities ranging from sub-primary data rates to 155 Mbit/s.[1]

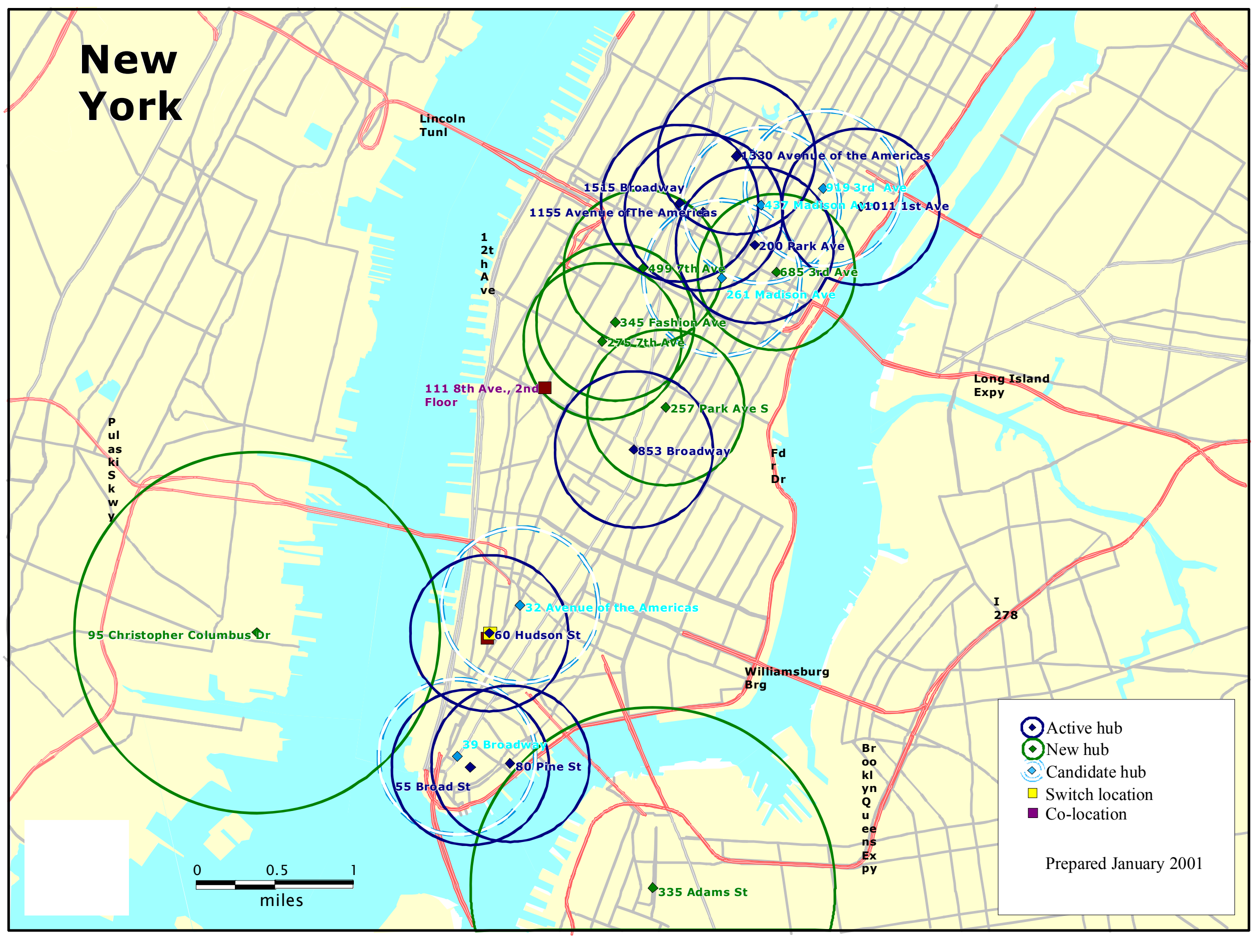
In this area, hub locations are typically on high-rise buildings, and subscriber stations are mounted on rooftops and/or elsewhere on or within the building. Line-of-sight hop lengths are limited to a few kilometres due to propagation conditions and high availability requirements. Distances may increase in low rain fade areas or due to lower availability requirements. P-P deployment densities, expressed by the number of 38 GHz stations per km^2 have already reached up to about 200 per km^2 in some instances and are moving higher. One operator reports a nationwide growth rate in link installation from January 1998 to December 2000 of approximately 400%. At the end of year 2000, one United States of America BWA provider had between 6 000 and 7 000 links.

Generally BWA links in metro areas have shorter ranges and typically operate at low fade margins. Moreover, P-P BWA systems with power control (adaptive transmitter power control (ATPC)) tend to be set up to operate much closer to the threshold in clear-sky conditions with appropriate transmitter power adjustments to meet the 99.999% availability. This can also be achieved with lowering power (ATPC, level setting and attenuator) and small antenna.

[1] Other applications in use or being tested for imminent use include 310 Mbit/s and 620 Mbit/s deployments.

FIGURE 4

Hub deployment in urban area, United States of America



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The 38 GHz band has been extensively licensed for FS use in the United States of America. There are now approximately 100 FS licensees in the 38 GHz band with over 3 500 area-wide licences. At least three of these United States of America licensees have licences covering 180 million people or more. These 38 GHz licensees are deploying a new type of FS wireless local network providing digital links directly to subscribers. The local networks interface with the public telecommunications network through local switches and fibre rings.

Subscriber links of up to 0.5 km in length account for about one third of the total installed base in all currently served metropolitan areas in the United States of America, links up to 0.75 km for about one half, and links up to 1 km in length for about two thirds of the total. Figures 5 and 6 illustrate the updated link length and elevation angle statistics. With increasing deployment densities, the expected general trend is toward progressively shorter link lengths. The pace at which densities will increase is generally not constricted for technical reasons, but instead is governed by business considerations, such as the acquisition of building access rights. 3G mobile deployments in urban areas, which will require substantial backhaul support, will further increase the link densities.

FIGURE 5

38 GHz link length distribution statistics in the United States of America for subscriber-based HDFS networks

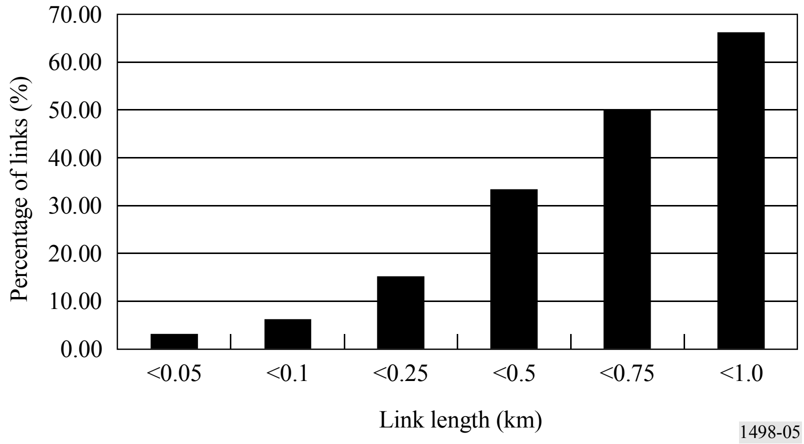
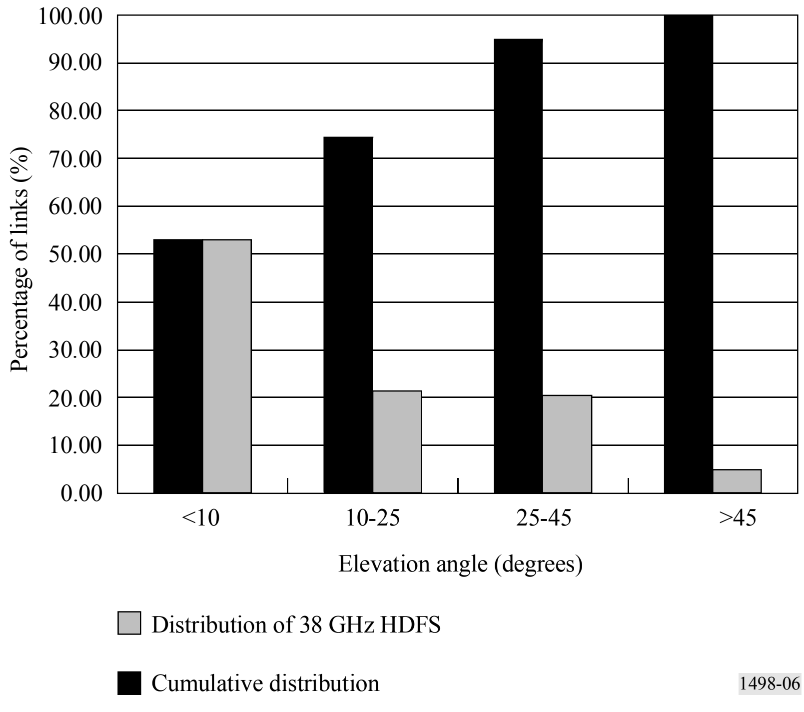


FIGURE 6

38 GHz HDFS elevation angle distribution in the United States of America



The deployment characteristics illustrated in Figs. 5 and 6 require a new set of link design trade-offs, primarily between spectral efficiency and performance and coverage, which greatly affect the competitiveness of BWA systems as substitutes for optical fibre access systems.

These links are usually engineered to provide 99.999% availability and to satisfy the up-to-date performance objectives. Due to the geographical distribution of subscriber-based BWA systems in the various ITU-R rain zones in the United States of America, about one third of all links satisfy the 99.999% requirement with rain margins up to 10 dB. Reducing the transmitter powers to levels that are as close as practicable to the required minimum satisfying the performance and availability objectives greatly helps to achieve high spectral efficiencies through frequency reuse. However, this makes FS systems more susceptible to interference from other services. Lower power levels can also be achieved using attenuators and smaller antennas. Since P-MP base stations have fixed power levels certain subscriber locations may have extra margin. Area-licensed 50 MHz channel pairs in the band 38.6-40 GHz enhance flexible service provisioning and spectral efficiency through frequency reuse, similar to cellular and personal communications service operators' practice in the mobile bands below 2 GHz.

Whereas the initial service in the band 38.6-40 GHz was based on the use of P-P systems with a simple modulation scheme, e.g. quadraphase shilt keying (QPSK), the development trend is toward both P-MP systems and more complex modulation schemes that substantially increase the spectral efficiency and offer higher transmission capacities. For example, a 64-quadrature amplitude modulation (64-QAM) P-MP system is capable of providing up to 250 Mbit/s in a 50 MHz radio channel, and a 128-QAM P-P system up to 310 Mbit/s in the same bandwidth. In the United States of America the combined P-P and P-MP station densities per km^2 are already reaching up to about 200 in some instances and continue to increase rapidly. This anticipated growth is contemplated by the licences already granted, and requires no new authorization.

In P-MP systems, unlike P-P systems, the base station antenna is either omnidirectional or sectoral. In each case the base station antenna is oriented to serve all the subscribers within the serving area of that base station. As a result the base station antenna will have less gain and directivity than in the case of the hub end of a series of P-P hops configured in a hub and spoke configuration. In the P-MP configuration the subscriber end of the path will operate with less receive signal level and will therefore require higher gain antennas to maintain an acceptable fade margin to compensate for rain attenuation.

Consistent with vertical radiation patterns of omnidirectional and sectoral antennas, the e.i.r.p. from the base station antenna will decrease as the subscriber terminal moves closer to the base station. This reduced signal strength is somewhat compensated for by the corresponding reduction in path length. However, the net effect is a reduction in signal strength and therefore a corresponding decrease in fade margin. Also, it follows that as the path between the hub and the subscriber decreases, the elevation angle of the subscriber terminal increases, thus reducing available atmospheric loss and increasing the susceptibility of the receiver to interference from satellite emissions.

The described local access services for mobile network infrastructures and direct subscriber access achieve high spectral efficiencies due to favourable frequency reuse conditions which derive from the propagation conditions that limit the usable line-of-sight hop lengths in the band 38 GHz to a few kilometres when 99.999% availability is required. Experience shows that area licensing stimulates operation at the highest possible spectral efficiencies, and simultaneously enables several local competitors to coexist in the same local market, in the same way as cellular and personal communications service operators do in the mobile bands below 2 GHz.

3.3 Emerging deployment example of 38 GHz FS systems in Brazil

In recent years, Brazil has experienced a tremendous growth in the deployment of P-P digital radio systems, mainly with transmission capacity ranging from 2 to 34 Mbit/s, for mobile telecommunication system back-haul connections, as well as for corporate wireless access applications, and digital network at frequency bands higher than 15 GHz. Besides low transmission capacity, new applications have been deployed in 38 GHz band in 155 Mbit/s systems providing digital network. Currently, in the metropolitan areas, due to the saturation at the lower frequency bands, the 38 GHz band have been authorized for the above applications. Currently (middle of 2001), about 2500 hops of P-P digital systems have been deployed, in the major Brazilian metropolitan cities. It is almost a 10-fold growth in 3.5 years considering that 260 hops were licensed by the end of 1997.

It is noticed that, in case of the 38 GHz band, the growth rate in the wireless access systems for data communications has been bigger than in mobile back-haul systems. Although, hops with high antenna elevation angles, as is the case in the United States of America, have not been reported yet, as consequence of the growth in the wireless access systems for data communication, it is envisaged that high elevation angles, in excess of 25° shall be deployed in the future.

It is also noticed that link length varies from a minimum value of 30 m to a maximum value of 2.8 km.

Furthermore, some trial systems of digital P-MP systems have been deployed, and the local administration is awaiting for trial's report to issue regulations in 2002 that will allow P-MP systems to enter in commercial service.

This is a good example of emerging FS systems deployments in the 38 GHz band.

3.4 Deployment example of 38 GHz FS systems in Japan

In Japan 38 GHz band has been used for subscriber-based fixed wireless links, which are operating under the 60 MHz paired frequency blocks given in Annex 3 (§ 2) to Recommendation ITU-R F.749.

On account of heavy rainfall in most parts of Japan it is a significant issue for operators to consider trade-off between hop length and link availability. Since high availability above 99.999% is becoming a basic requirement of users, hop length of FWA links in the 38 GHz band is limited to the order of 1 km. The typical system capacity is 6 Mbit/s to 155 Mbit/s to meet broadband service applications.

The link length and elevation angle distributions are illustrated in Fig. 7 and Fig. 8, respectively. Since it is not long before the initial 38 GHz system was placed in service in Japan, the routes in Figs. 7 and 8 include those in the planning stage in order to provide statistically effective data.

FIGURE 7

Link length distribution of potential 38 GHz HDFS routes in Japan

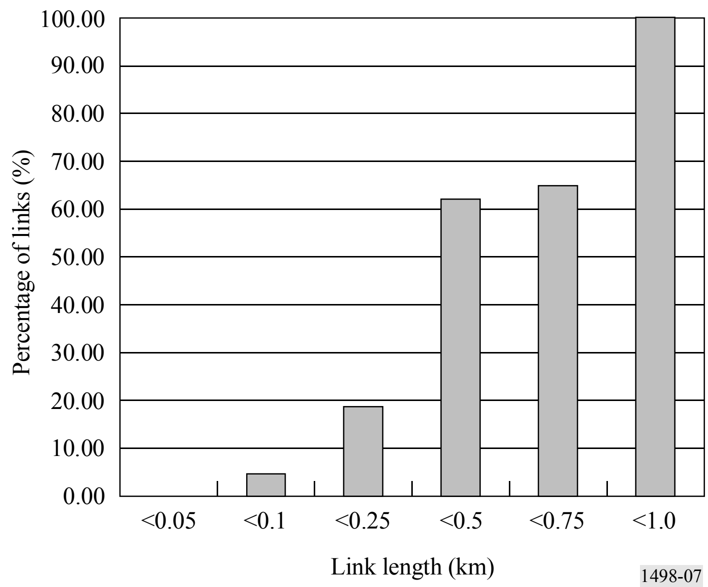
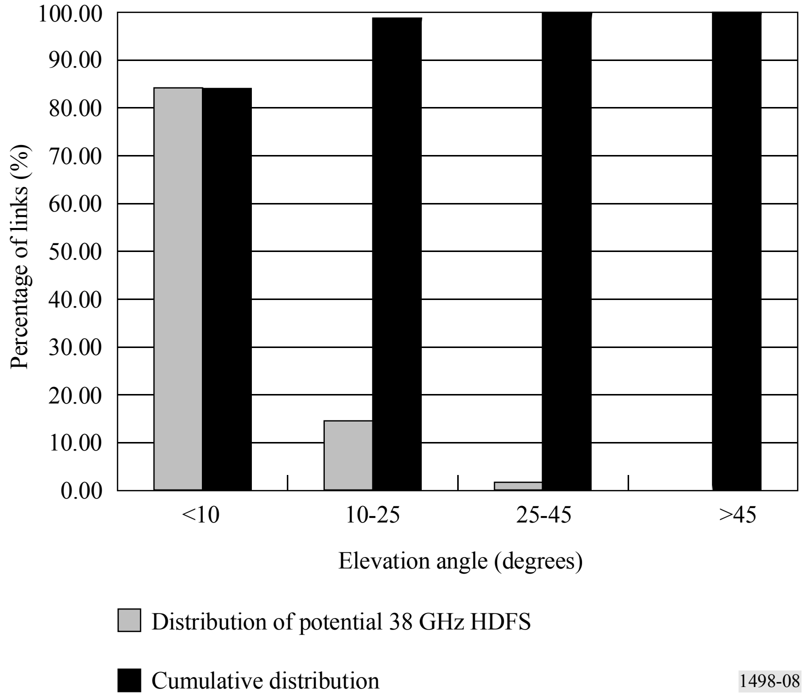


FIGURE 8

Elevation angle distribution of potential 38 GHz HDFS routes in Japan



4 Expected trend of systems deployment

While the current major use of the 38 GHz band in many countries is the application of P-P systems with capacities of a multiple of the primary rate using systems with 4 level modulation methods and partly 155 Mbit/s systems with 16 level modulation, in the future higher capacities up to $n \times 155$ Mbit/s can be expected; these higher capacities might use higher level modulation methods (e.g. 128-QAM).

For all types of P-MP systems adaptive modulation schemes (i.e. between 4 to 64 levels) partly already known from frequency division multiple access systems, fast capacity switching to support asynchronous transfer mode (ATM)-traffic and steering antennas might improve future systems in terms of availability, link length, required bandwidth and interference.

The key to all future deployment is to increase the capacity that can be provided to potential customer locations. Certainly improving on technology as indicated in the preceding paragraphs is one way to increase capacity. Another way to increase capacity is to more efficiently deploy BWA systems. Below is a discussion as to how HDFS BWA systems are currently evolving to deliver more capacity in a given area.

4.1 Summary of deployments to date

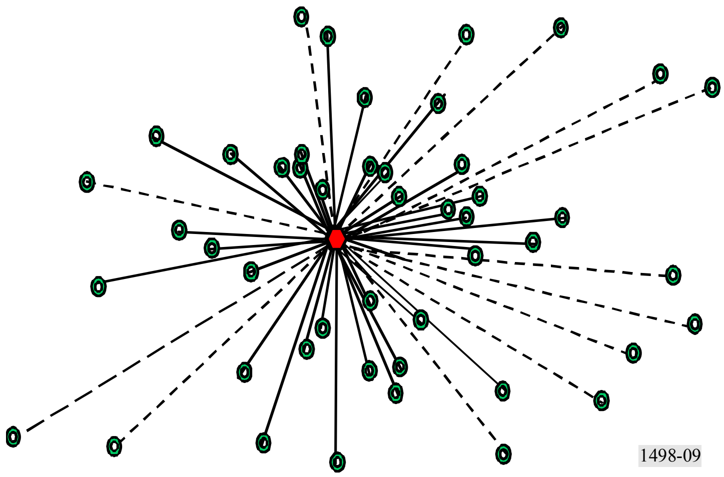
Current statistics of HDFS deployments to date have been provided in earlier sections of this Annex. These statistics help portray how BWA have been deployed and how the deployment differs from a typical FS deployment. Records show that most of the links deployed to date have elevation angles that are less than 10° apart from the United States of America where almost half of the links deployed to date have elevation angles that are greater than 10°. Moreover, one third of the BWA links deployed in the United States of America are less than 0.5 km in length and about half are less than 0.75 km in length.

4.2 Discussion of frequency reuse in a star topology

Traditionally when an BWA system is deployed a strategically located building is chosen that has line-of-sight to as many potential candidate building locations as possible within the designated area in order to maximize the coverage area. This is known as a star topology. An example of star topology is shown in Fig. 9. A coverage area in a BWA star topology is limited by two factors: line-of-sight and rain outage limitations that will allow for 99.999% availability. In the continental United States these distances are limited to a radius of less than 1.9 km for 45 Mbit/s capacity within a D2 rain zone. (This equates to an area of 11.7 km^2.) While it is true that extending coverage to the maximum range possible provides the most coverage it is also true that frequency reuse is minimized in this case.

FIGURE 9

Star topology of a BWA hub location



By extending the distance of a link out to the maximum distance allowed by the system gain and sensitivity of BWA equipment a frequency can only be reused every 60°. Figure 10 provides an example of how a frequency used at a hub site can be reused to the maximum extent of six times. If, on the other hand, one limits the distance to 0.8 km a frequency can be reused up to 36 times. Figure 11 shows pictorially how reuse is increased by limiting the distance to 0.8 km or less. The spectrum efficiencies are achieved by keeping the power levels at a minimum while also taking into account that rain attenuation is much more limited at smaller distances than longer distances.

FIGURE 10

Frequency reuse achieved with links at maximum distance of 1.9 km

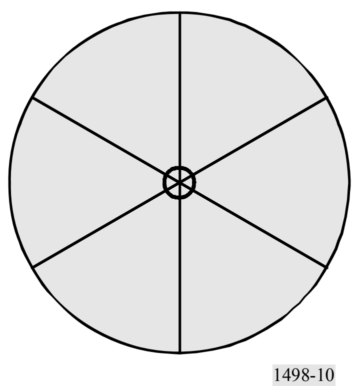
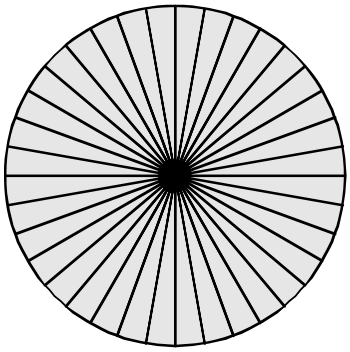


FIGURE 11

Frequency reuse achieved by limiting distance to 0.8 km



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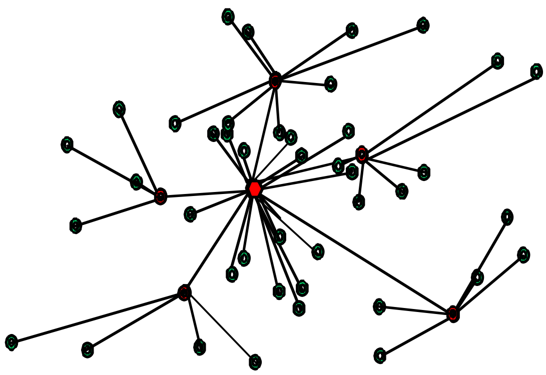
One other limitation that exists with a BWA star topology is that line-of-sight to targeted buildings is never 100% even when one selects the tallest building in the area. This poses a challenge to reach as many buildings as possible without having to add additional and costly hub locations.

4.3 Current view of network topology

The current implementation strategy under way to maximize frequency reuse is to both reduce the range covered by a BWA hub location as well as increase the coverage. This is being done by adding small extended range points (SERPs) to existing hubs. The topology is indicated in Fig. 12. Adding these SERPs provides several benefits. It allows the link length to be reduced while also increasing the probability of having line-of-sight to candidate buildings.

FIGURE 12

Topology using SERPs using consecutive wireless links



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One important aspect of this SERP topology is that access to the network will require the customer to traverse two or more wireless links. This means that in order for the end user to achieve 99.999% availability the composite availability of both link A and link B needs to be 99.999%. The implication here is that most links will be limited to the 0.8 km distance limitation and as a result be operating at very low fade margin. Additionally, along with the shorter path lengths and smaller fade margins will be a much higher percentage of links operating with high elevation angles.

4.4 Statistics on new network topology

It must be also pointed out that when the distance on a link decreases the average elevation angle increases. Clearly links that are closer in to the serving BWA hub site have a much higher probability of having a larger elevation angle than links that are further away. The degree of difference is dependent on the local building distribution and heights and is very dependent on the relative height of the serving BWA hubs site.

To evaluate the relative increase in elevation angle two hub locations were selected for evaluation; one on a tall building and a large United States of America city relative to the local environment and the other in a smaller United States of America city with relatively smaller hub height. Both of the hub locations selected are actual locations offering or targeted to offer BWA service. This analysis will provide the range of variation that one can expect for the two extremes in BWA deployment as it relates to elevation angles. Buildings heights were gathered for all targeted buildings that are within the rain radius of the two assessed hubs. Table 2 shows the average elevation angle breakdown for links that are less than 0.8 km in length and those that are greater than 0.8 km in length but still within the rain limitation for 99.999% availability. As can be seen the average elevation angle increases in both cases for small and large buildings between 230% and 380% respectively as the distance is limited to 0.8 km.

TABLE 2

Average elevation angles for two United States of America BWA hubs

Distance (km)	**Elevation angle (small city) (degrees)**	**Elevation angle (big city) (degrees)**
Less than 0.8	7.7	19.6
More than 0.8	2.0	8.6

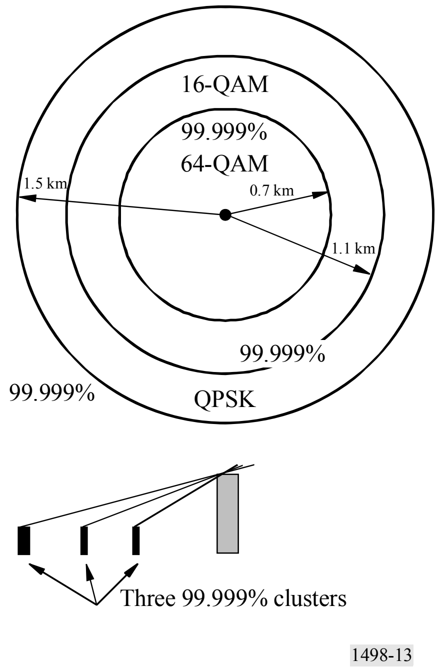
As indicated earlier it is expected that in order to maintain spectrum efficiency there will be a continued increase in the number and percentage of links deployed within the 0.8 km radius. Even in the smaller market with a much lower hub height the average elevation angle will be close to 8°.

4.5 Adaptive modulation

Emerging BWA technologies (time division duplex and frequency division duplex) may operate on three modulations simultaneously (see Fig. 13) in the same RF carrier: QPSK, 16-QAM and 64-QAM. These deployments increase network capacity considerably and result in a single cell having three distinct rings where subscribers are at the limiting availability, say 99.999%, i.e. links to these subscribers may have no excess fade margin. This can result in an increased number of subscribers affected by inter-service interference. Statistically, the largest percentage of subscribers is close to the HDFS base station and thus has higher elevation angles coinciding with those availability thresholds. These close-in subscribers also meet the criteria for 64-QAM service which demands higher C/I ratios. It should be noted that close in P-MP subscribers may have excess margin as the hub terminal power is fixed.

FIGURE 13

BWA cell employing three different modulations simultaneously in rain zone (CRANE model in region K)



5 Considerations regarding the determination of the coordination area in respect to the FS

In general, coordination between FS stations and FSS earth stations can be exemplified by the following scenarios:

Scenario 1: Areas without FS deployment

The geographical areas in which the FSS will not need to coordinate with the FS will be larger in the 37-40 GHz band in comparison with the currently shared lower frequency bands where the FS deployment is spread out over much larger geographical areas.

Scenario 2: Areas with sparse FS deployment

In intermediate cases, where the FS is sparsely deployed, station-to-station coordination is feasible.

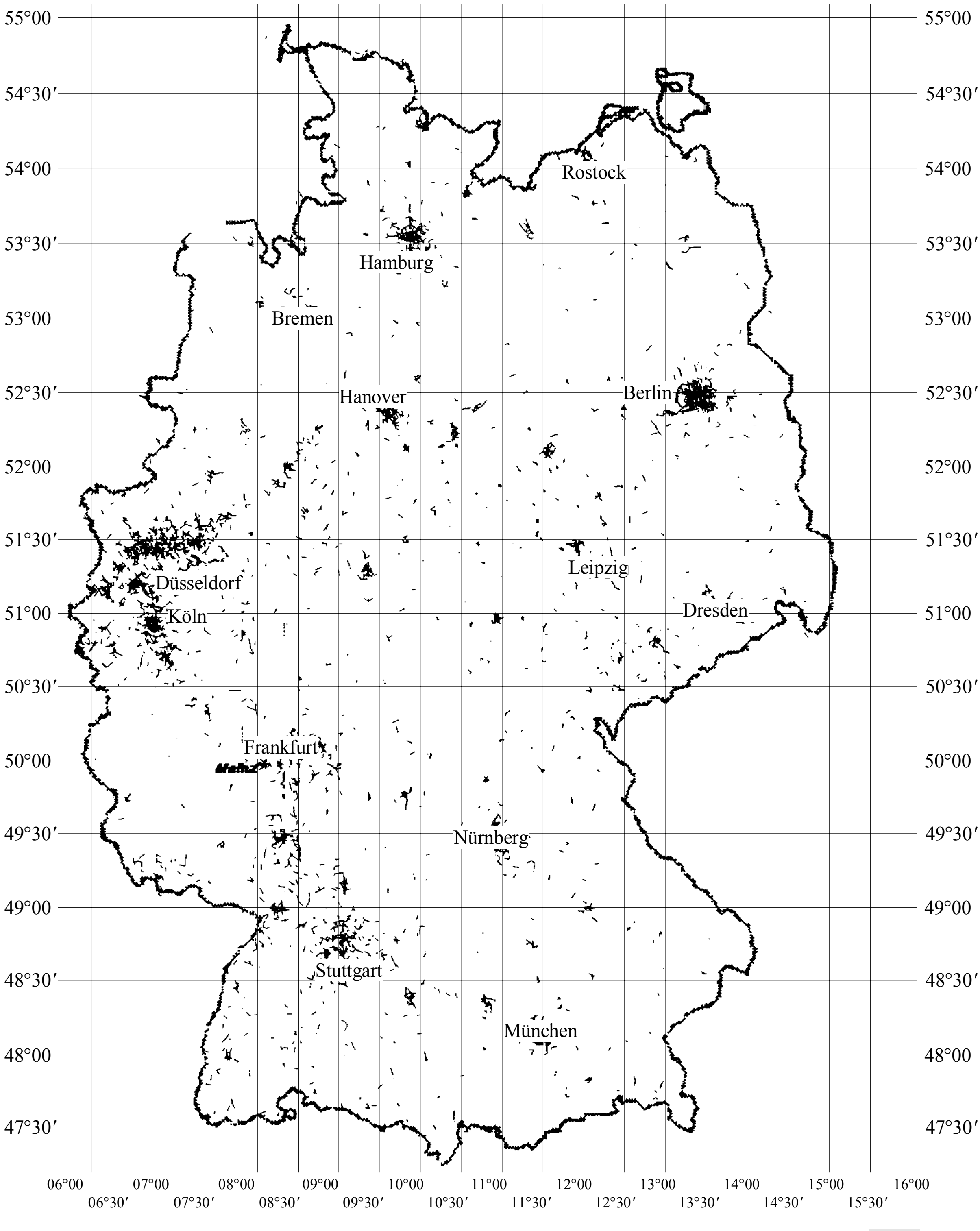
Scenario 3: Areas with dense FS deployment

In service deployment areas where there is dense deployment of FS stations, coordination with and by FSS earth stations should be carried out on a basis other than a station-to-station basis. CPM-97 reported in section 7.5.3.2, § 1, that because high-density FS intra-service station distances are substantially smaller than interservice separation distances, coordination with and by other services should be carried out for high-density FS service areas instead of individual high-density FS stations.

These three deployment scenarios are illustrated in Fig. 14.

FIGURE 14

38 GHz deployment in Germany by the end of 2000



The following additional considerations are of key importance to any coordination between FS stations and FSS earth stations:

– Both the FS and the FSS need to assure line-of-sight coverage of their subscriber base. The fact that FS hub stations are being placed in exposed locations, such as on top of high-rise buildings in many cases, reduces the opportunity to use natural or man-made shielding by the FSS in order to reduce the separation distance. In those instances, most interference paths would have line-of-sight propagation conditions.

– Under area-wide licensing, service is implemented using both P-P and P-MP FS systems. The use of sectoral antennas in the hub stations of P-MP systems is more restrictive to coordination. Such antennas cover a segment of 360° or are stacked for omnidirectional service area coverage, as required. Sectoral antennas reduce the benefits of using angle discrimination in coordination, as compared to parabolic antennas. The actual required separation distance between the FS transmitter and the FSS receiver depends on the actual parameters of both systems, such as FS transmitter power density, minimum operational elevation angles of satellite systems, off-axis antenna gain of both systems, and the terrain topography.

In conclusion HDFS characteristics are uniquely different from the classical FS and backbone infrastructure links. As systems, such as 3G, *et al*. are implemented they will most likely be deployed in pico-cells within micro-cells and act as collector-distributor systems for HDFS and FS backbones as aggregators for further transport to service nodes that include switches, etc.

6 Uncorrelated fading

In cases where a satellite uses downlink power control, uncorrelated rain fading needs to be considered in sharing studies between FS and FSS deployments. A narrow FSS satellite spot beam directed at an earth station has a footprint of at least 200 km. Considering that typical rain cells range between 1 and 5 km (Recommendation ITU-R P.452), subscribers outside the rain cell could receive increased I/N levels, thereby degrading C/I. Figure 15 describes such a situation where an FSS gateway is implemented within the HDFS deployment area. A C/I degradation considered unacceptable can be mitigated by locating the gateway outside the HDFS deployment area.

It should be noted that, due to interference from HDFS, gateway earth stations are unlikely to be implemented in HDFS areas.

FIGURE 15

Uncorrelated rain fading condition