Chapter 1 : 60 GHz Line of Sight Backhaul Links Ready to Boost Cellular Capacity | Analog Devices

Digital communications, Line-of-sight radio links, Microwave communication systems, Mobile communication systems About the Book There's no description for this book yet.

The resultant vector then runs from this point to the upper end of the spiral at point Y. But how do we calculate whether we have the required clearance? The geometry for Fresnel zone calculations is shown in Fig. Keep in mind that this is only a two-dimensional representation, but Fresnel zones are three-dimensional. The same considerations apply when the objects limiting path clearance are to the side or even above the radio path. Since we are considering LOS paths in this section, we are dealing only with the "negative height" case, shown in the lower part of the figure. We will look at the case where h is positive later, when we consider non-LOS paths. For first Fresnel zone clearance, the distance h from the nearest point of the obstacle to the direct path must be at least 9 where d1 and d2 are the distances from the tip of the obstacle to the two ends of the radio circuit. This formula is an approximation which is not valid very close to the endpoints of the circuit. For convenience, the clearance can be expressed in terms of frequency: Figure 7 Fresnel Zone Geometry Example 2. The path profile indicates that the high point on the path is 3 km from one end, and the direct path clears it by about 18 meters 60 ft. Fresnel zone clearance may not seem all that important - after all, we said previously that for the zero clearance grazing case, we have 6 dB of additional path loss. If necessary, this could be overcome with, for example, an additional 3 dB of antenna gain at each end of the circuit. Basically, this means that the top of the obstacle is small in terms of wavelengths. This is sometimes a reasonable approximation of an object in the real world, but more often than not, the obstacle will be rounded such as a hilltop or have a large flat surface like the top of a building , or otherwise depart from the knife edge assumption. In such cases, the path loss for the grazing case can be considerably more than 6 dB - in fact, 20 dB would be a better estimate in many cases. So, Fresnel zone clearance can be pretty important on real-world paths. And, again, keep in mind that the Fresnel zone is three-dimensional, so clearance must also be maintained from the sides of buildings, etc. Another point to consider is the effect on Fresnel zone clearance of changes in atmospheric refraction, as discussed in the last section. We may have adequate clearance on a longer path under normal conditions i. On longer paths, therefore, it is common in commercial radio links to do the Fresnel zone analysis on something close to "worst case" rather than typical refraction conditions, but this may be less of a concern in amateur applications. Most of the material in this section was based on Ref. Ground Reflections An LOS path may have adequate Fresnel zone clearance, and yet still have a path loss which differs significantly from free space under normal refraction conditions. One common source of reflections is the ground. It tends to be more of a factor on paths in rural areas; in urban settings, the ground reflection path will often be blocked by the clutter of buildings, trees, etc. In paths over relatively smooth ground or bodies of water, however, ground reflections can be a major determinant of path loss. For any radio link, it is worthwhile to look at the path profile and see if the ground reflection has the potential to be significant. It should also be kept in mind that the reflection point is not at the midpoint of the path unless the antennas are at the same height and the ground is not sloped in the reflection region - just the remember the old maxim from optics that the angle of incidence equals the angle of reflection. Ground reflections can be good news or bad news, but are more often the latter. In a radio path consisting of a direct path plus a ground-reflected path, the path loss depends on the relative amplitude and phase relationship of the signals propagated by the two paths. In extreme cases, where the ground-reflected path has Fresnel clearance and suffers little loss from the reflection itself or attenuation from trees, etc. Then, depending on the relative phase shift of the two paths, we may have an enhancement of up to 6 dB over the direct path alone, or cancellation resulting in additional path loss of 20 dB or more. If you are acquainted with Mr. Murphy, you know which to expect! The difference in path lengths can be estimated from the path profile, and then translated into wavelengths to give the phase relationship. Then we have to account for the reflection itself, and this is where things get interesting. The amplitude and phase of the reflected wave depend on a number of variables, including conductivity and permittivity of the reflecting surface, frequency, angle of incidence, and polarization. It is difficult to summarize the effects of all of the variables which affect ground reflections, but a typical case is shown in Fig. This particular figure is for typical ground conditions at MHz, but the same behavior is seen over a wide range of ground constants and frequencies. Notice that there is a large difference in reflection amplitudes between horizontal and vertical polarization denoted on the curves with "h" and "v", respectively , and that vertical polarization in general gives rise to a much smaller reflected wave. However, the difference is large only for angles of incidence greater than a few degrees note that, unlike in optics, in radio transmission the angle of incidence is normally measured with respect to a tangent to the reflecting surface rather than a normal to it ; in practice, these angles will only occur on very short paths, or paths with extraordinarily high antennas. For typical paths, the angle of incidence tends to be of the order of one degree or less - for example, for a 10 km path over smooth earth with 10 m antenna heights, the angle of incidence of the ground reflection would only be about 0. In such a case, both polarizations will give reflection amplitudes near unity i. Perhaps more surprisingly, there will also be a phase reversal in both cases. Horizontally-polarized waves always undergo a phase reversal upon reflection, but for vertically-polarized waves, the phase change is a function of the angle of incidence and the ground characteristics. Figure 8 Typical Ground Reflection Parameters The upshot of all this is that for most paths in which the ground reflection is significant and no other reflections are present , there will be very little difference in performance between horizontal and vertical polarization. For very short paths, horizontal polarization will generally give rise to a stronger reflection. If it turns out that this causes cancellation rather than enhancement, switching to vertical polarization may provide a solution. In other words, for shorter paths, it is usually worthwhile to try both polarizations to see which works better of course, other factors such as mounting constraints and rejection of other sources of multipath and interference also enter into the choice of polarization. As stated above, for either polarization, as the path gets longer we approach the case where the ground reflection produces a phase reversal and very little attenuation. At the same time, the direct and reflected paths are becoming more nearly equal. The path loss ripples up and down as we increase the distance, until we reach the point where the path lengths differ by just one-half wavelength. It can be shown that, in this region, the received power follows an inverse fourth-power law as a function of distance instead of the usual square law i. The distance at which the path loss starts to increase at the fourth-power rate is reached when the ellipsoid corresponding to the first Fresnel zone just touches the ground. A reasonably good estimate of this distance can be calculated from the equation 11 where h1 and h2 are the antenna heights above the ground reflection point. So, for longer-range paths, ground reflections are always bad news. Serious problems with ground reflections are most commonly encountered with radio links across bodies of water. In other cases, it may be possible to adjust the antenna locations so as to move the reflection point to a rough area of land which scatters the signal rather than creating a strong specular reflection. Other Sources of Reflections Much of what has been said about ground reflections applies to reflections from other objects as well. The "ground reflection" on a particular path may be from a building rooftop rather than the ground itself, but the effect is much the same. On long links, reflections from objects near the line of the direct path will almost always cause increased path loss - in essence, you have a permanent "flat fade" over a very wide bandwidth. Reflections from objects which are well off to the side of the direct path are a different story, however. This is a frequent occurrence in urban areas, where the sides of buildings can cause strong reflections. In such cases, the angle of incidence may be much larger than zero, unlike the ground reflection case. This means that horizontal and vertical polarization may behave quite differently - as we saw in Fig. When the reflecting surface is vertical, like the side of a building, a signal which is transmitted with horizontal polarization effectively has vertical polarization as far as the reflection is concerned. Therefore, horizontal polarization will generally result in weaker reflections and less multipath than vertical polarization in these cases. Effects of Rain, Snow and Fog The loss of LOS paths may sometimes be affected by weather conditions other than the refraction effects which have already been mentioned. Rain and fog clouds become a significant source of attenuation only when we get well into the microwave region. Attenuation from fog only becomes noticeable i. Snow is in this category as well. Path Loss on Non-Line of Sight Paths We have spent quite a bit of time looking at LOS paths, and described the mechanisms which often cause them to have path loss which differs from the "free space" assumption. When we have a path which is not LOS, it becomes even more difficult to predict how well signals will propagate over it. Unfortunately, non-LOS situations are sometimes unavoidable, particularly in urban areas. The following sections deal with some of the major factors which must be considered. Diffraction Losses In some special cases, such as diffraction over a single obstacle which can be modeled as a knife edge, the loss of a non-LOS path can be predicted fairly readily. This parameter, from equation 8 , is To get d, measure the straight-line distance between the endpoints of the link. Then measure the length of the actual path, which includes the two endpoints and the tip of the knife edge, and take the difference between the two. The geometry is shown in Fig. A good approximation to the knife-edge diffraction loss in dB can then be calculated from 12 Example 3. We want to run a MHz link between two points which are a straight-line distance of 25 km apart. However, 5 km from one end of the link, there is a ridge which is meters higher than the two endpoints. Assuming that the ridge can be modeled as a knife edge, and that the paths from the endpoints to the top of ridge are LOS with adequate Fresnel zone clearance, what is the expected path loss? From simple geometry, we find that length of the path over the ridge is 25, Substituting this into 12 , we find that the expected diffraction loss is The free space path loss for a 25 km path at MHz is, from equation 6a , This is too lossy a path for many WLAN devices. This will produce, at the antenna terminals at the other end of the link, a received power of 36 - On the other hand, a lower-speed system may be quite usable over this path. For instance, the FreeWave Kbps modems require only about dBm for reliable operation, which is a comfortable margin below our predicted signal levels. To see the effect of operating frequency on diffraction losses, we can repeat the calculation, this time using MHz, and find the predicted diffraction loss to be Figure 9 Diffraction by a Rounded Obstacle Unfortunately, the paths which digital experimenters are faced with are seldom this simple. The path losses will generally be substantially greater in these cases than predicted by the single knife edge model. The paths will also often pass through objects such as trees and wood-frame buildings which are semi-transparent at radio frequencies. Many models have been developed to try and predict path losses in these more complex cases. The most successful are those which deal with restricted scenarios rather than trying to cover all of the possibilities. One common scenario is diffraction over a single obstacle which is too rounded to be considered a knife edge. There are different ways of treating this problem; the one described here is from Ref.

Chapter 2 : Line of Sight Radios - General Dynamics Mission Systems

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Press the Enter key or click the Search Icon to get general search results 2. Click a suggested result to go directly to that page 3. Click Search to get general search results based on this suggestion 4. Many of these new cells will be placed indoors where the majority of traffic originates and fiber is the top choice to funnel the traffic back into the networks. But there are many outdoor locations where fiber is not available or is too expensive to connect, and for these situations wireless backhaul is the most viable alternative. However, the bandwidth is limited and interference from other users of this spectrum is almost guaranteed due to heavy traffic and wide antenna patterns. Communication links of 60 GHz are emerging as a leading contender to provide these backhaul links for the many thousands of outdoor cells that will be required to meet capacity demands. This spectrum is also unlicensed, but unlike frequencies below 6 GHz, it contains up to 9 GHz of available bandwidth. Moreover, the high frequency allows for very narrow and focused antenna patterns that are somewhat resistant to interference, but require LOS paths. FPGA-based and SoC-based modems are increasingly being used in various wireless backhaul solutions since platforms using them can be modular and customizable, thereby reducing the total cost of ownership for OEMs. For the radio portion of these links, transceivers have been integrated into silicon-based ICs and packaged into low cost, surface-mount parts. Commercial parts are available to build a complete 60 GHz two-way data communication link as exemplified by the solution in Figure 1. This link meets the performance and flexibility requirements of the small cell backhaul market. High level block diagram of the complete two-way data communication link. As depicted in Figure 1, two nodes are required to create this link. Each node contains a transmitter with a modulator and its associated analog transmitter chain, and a receiver with a demodulator and its associated analog receiver chain. The modem card is integrated with analog and discrete devices. It contains oscillators implemented digitally to ensure the accuracy of frequency synthesis, and all the digital functions are executed in an FPGA or system on chip SoC. Robust modem design techniques reduce the phase noise implications of the local oscillators. Powerful low density parity check LDPC coding is included for improved performance and link budget. Millimeter Wave Modem The millimeter wave modem enables infrastructure vendors to develop flexible, cost optimized, and customizable links for their wireless backhaul networks. The solution presents operators with the ability to build scalable and field upgradable systems. Figure 2 further details the digital modem, as implemented in an SoC-based solution. All programmable SoC for wireless modem applications. This SoC platform is used to perform various data and control functions and to enable hardware acceleration. An integrated millimeter wave modem complete with PHY, controller, system interfaces, and a packet processor is shown in Figure 2. However, based on the required architecture, you could insert, update, or remove different modules. For instance, you might choose to implement an XPIC combiner so that you could use the modem in cross polarization mode with another modem. Some of the other important features of the modem IP include automatic hitless and errorless state switching through adaptive coding and modulation ACM to keep the link operational; adaptive digital closed-loop predistortion DPD to improve RF power amplifier efficiency and linearity; synchronous Ethernet SyncE to maintain clock synchronization and Reed-Solomon or LDPC forward error correction FEC. The FEC choice is based on the design requirements. The result is noticeable SNR gains. You can apply different levels of parallelism by varying the number of iterations of the LDPC core, thereby optimizing the size and power of the decoder. You can also model the design based on channel bandwidth and throughput constraints. This modem solution also comes with a graphical user interface GUI for both display and debug, and it is capable of high level functions such as channel bandwidth or modulation selection, as well as low level functions, such as setting of hardware registers. Millimeter Wave Transceiver Chipset Analog Devices optimized its second-generation, silicon-germanium SiGe 60 GHz chipset used in this design for small cell backhaul applications. The transmitter chip is a complete analog baseband to millimeter wave upconverter. Output power has increased to roughly 16 dBm linear power, while an integrated power detector monitors the output power so it does not exceed the regulatory limits. The transmitter chip offers either analog control or digital control of the IF and RF gains. Analog gain control is sometimes needed when using higher order modulations since discrete gain changes can be mistaken for amplitude modulation, leading to bit errors. A built-in SPI interface supports digital gain control. Figure 3 shows a block diagram of the transmitter chip, which supports up to 1. An MSK modulator option enables low cost data transmissions up to 1. Complementing this device is a receiver chip, likewise optimized to meet the demanding requirements of small cell backhaul applications. Other key features include a low 6 dB noise figure at the maximum gain settings; adjustable low-pass baseband filters and high-pass baseband filters; the same new synthesizers as found in the transmitter chip to support 64 QAM modulation over the 57 GHz to 66 GHz band and either analog or digital control of the IF and RF gains. A block diagram of the receiver chip is shown in Figure 4. These surface-mount parts will enable low cost manufacturing of radio boards for backhaul applications. A block diagram of an example millimeter wave modem and radio system is shown in Figure 5. In addition to the FPGA, modem software, and millimeter wave chipset, the design also contains a number of other components.

Chapter 3 : Radio Line of Sight Calculator for use on VHF/UHF Ham Bands

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DAB is not used in the United States. This used up a comparatively large amount of spectrum for a relatively small number of stations, limiting listening choice. DAB is a digital radio broadcasting system that through the application of multiplexing and compression combines multiple audio streams onto a relatively narrow band centred on a single broadcast frequency called a DAB ensemble. Within an overall target bit rate for the DAB ensemble, individual stations can be allocated different bit rates. The number of channels within a DAB ensemble can be increased by lowering average bit rates, but at the expense of the quality of streams. Error correction under the DAB standard makes the signal more robust but reduces the total bit rate available for streams. That multiplex is then subdivided into multiple digital streams of between 9 and 12 programs. The full bandwidth of the hybrid mode approaches kHz. HD Radio is a proprietary system from the company IBiquity. Use of frequency spectrum and transmitter sites[edit] DAB can give substantially higher spectral efficiency , measured in programmes per MHz and per transmitter site, than analogue systems. In many places, this has led to an increase in the number of stations available to listeners, especially outside of the major urban areas. Analog FM requires 0. The frequency reuse factor in most countries is approximately 15 for stereo transmissions with lesser factors for mono FM networks , meaning in the case of stereo FM that only one out of 15 transmitter sites can use the same channel frequency without problems with co-channel interference , i. Assuming a total availability of FM channels at a bandwidth of 0. Note the above capacity improvement may not always be achieved at the L-band frequencies, since these are more sensitive to obstacles than the FM band frequencies, and may cause shadow fading for hilly terrain and for indoor communication. The number of transmitter sites or the transmission power required for full coverage of a country may be rather high at these frequencies, to avoid the system becoming noise limited rather than limited by co-channel interference. MP2 quality The original objectives of converting to digital transmission were to enable higher fidelity , more stations and more resistance to noise, co-channel interference and multipath than in analogue FM radio. However, many countries in implementing DAB on stereo radio stations use compression to such a degree that it produces lower sound quality than that received from FM broadcasts. This is because of the bit rate levels being too low for the MPEG Layer 2 audio codec to provide high fidelity audio quality. DAB can carry "radiotext" in DAB terminology, Dynamic Label Segment, or DLS from the station giving real-time information such as song titles, music type and news or traffic updates, of up to characters in length. The DAB transmission contains a local time of day and so a device may use this to automatically correct its internal clock when travelling between time zones and when changing to or from Daylight Saving. More stations[edit] DAB is not more bandwidth efficient than analogue measured in programmes per MHz of a specific transmitter the so-called link spectral efficiency , but it is less susceptible to co-channel interference cross talk , which makes it possible to reduce the reuse distance , i. The system spectral efficiency the average number of radio programmes per MHz and transmitter is a factor three more efficient than analogue FM for local radio stations. For national and regional radio networks, the efficiency is improved by more than an order of magnitude due to the use of SFNs. In that case, adjacent transmitters use the same frequency. In certain areas â€" particularly rural areas â€" the introduction of DAB gives radio listeners a greater choice of radio stations. For instance, in Southern Norway , radio listeners experienced an increase in available stations from 6 to 21 when DAB was introduced in November Reception quality[edit] The DAB standard integrates features to reduce the negative consequences of multipath fading and signal noise , which afflict existing analogue systems. However, radios in the fringe of a DAB signal, can experience a "bubbling mud" sound interrupting the audio or the audio cutting out altogether. In cities such as London with large numbers of unlicensed radio stations broadcasting on FM, this means that some stations can be reliably received via DAB in areas where they are regularly difficult or impossible to receive on FM because of interference from unlicensed radio stations. Variable bandwidth[edit] Mono talk radio, news and weather channels and other non-music programs need significantly less bandwidth than a typical music radio station, which allows DAB to carry these programmes at lower bit rates, leaving more bandwidth to be used for other programs. However, this led to the situation where some stations are being broadcast in mono; see music radio stations broadcasting in mono for more details. Transmission costs[edit] DAB transmitters are inevitably more expensive than their FM counterparts. DAB uses higher frequencies than FM and therefore there may be a need to compensate with more transmitters to achieve the same coverage as a single FM transmitter. DAB is commonly transmitted by a different company from the broadcaster who then sells the capacity to a number of radio stations. This shared cost can work out cheaper than operating an individual FM transmitter. It is also argued that the power consumption will be lower for stations transmitted on a single DAB multiplex compared with individual analog transmitters. The reason for this is that the DAB uses weak error correction coding , so that when there are a lot of errors with the received data not enough of the errors can be corrected and a "bubbling mud" sound occurs. In some cases a complete loss of signal can happen. Like with other digital systems, when the signal is weak or suffers severe interference, it will not work at all. DAB reception may also be a problem for receivers when the wanted signal is adjacent to a stronger one. This was a particular issue for early and low cost receivers. Having few digital channels broadcasting in stereo. Signal delay[edit] The nature of a single-frequency network SFN is such that the transmitters in a network must broadcast the same signal at the same time. To achieve synchronization, the broadcaster must counter any differences in propagation time incurred by the different methods and distances involved in carrying the signal from the multiplexer to the different transmitters. This is done by applying a delay to the incoming signal at the transmitter based on a timestamp generated at the multiplexer, created taking into account the maximum likely propagation time, with a generous added margin for safety. Delays in the audio encoder and the receiver due to digital processing e. DAB radios are out of step with live events, so the experience of listening to live commentaries on events being watched is impaired; Listeners using a combination of analogue AM or FM and DAB radios e. Time signals , on the contrary, are not a problem in a well-defined network with a fixed delay. The DAB multiplexer adds the proper offset to the distributed time information. The time information is also independent from the possibly varying audio decoding delay in receivers since the time is not embedded inside the audio frames. This means that built in clocks in receivers can be precisely correct. Transmission costs[edit] DAB can provide savings for networks of several stations. The original development of DAB was driven by national network operators with a number of channels to transmit from multiple sites. However, for individual stations such as small community or local stations which traditionally operate their own FM transmitter on their own building the cost will be much higher. Operating a DAB transmitter for a single station is not an efficient use of spectrum or power. Coverage[edit] Although FM coverage still exceeds DAB coverage in most countries implementing any kind of DAB services, a number of countries moving to digital switchover have undergone significant DAB network rollouts. As of , the following coverages were given by WorldDAB:

Chapter 4 : Digital line-of-sight radio links (edition) | Open Library

Line-of-sight propagation is a characteristic of electromagnetic radiation or acoustic wave propagation which means waves travel in a direct path from the source to the receiver. Electromagnetic transmission includes light emissions traveling in a straight line.

Low-powered microwave transmitters can be foiled by tree branches, or even heavy rain or snow. The presence of objects not in the direct line-of-sight can cause diffraction effects that disrupt radio transmissions. For the best propagation, a volume known as the first Fresnel zone should be free of obstructions. Reflected radiation from the surface of the surrounding ground or salt water can also either cancel out or enhance the direct signal. This effect can be reduced by raising either or both antennas further from the ground: The reduction in loss achieved is known as height gain. See also Non-line-of-sight propagation for more on impairments in propagation. It is important to take into account the curvature of the Earth for calculation of line-of-sight paths from maps, when a direct visual fix cannot be made. Mobile telephones[edit] Although the frequencies used by mobile phones cell phones are in the line-of-sight range, they still function in cities. This is made possible by a combination of the following effects: For mobile phone services, these problems are tackled using: A phone can typically see at least three, and usually as many as six at any given time. This allows the base station to use a directional antenna that is pointing at the user, which improves the signal to noise ratio. If the user moves perhaps by walking or driving from one antenna sector to another, the base station automatically selects the proper antenna. Electromagnetic radiation is blocked where the wavelength is longer than any gaps. For example, mobile telephone signals are blocked in windowless metal enclosures that approximate a Faraday cage, such as elevator cabins, and parts of trains, cars, and ships. The same problem can affect signals in buildings with extensive steel reinforcement. Two stations not in line-of-sight may be able to communicate through an intermediate radio repeater station. Radar horizon The radio horizon is the locus of points at which direct rays from an antenna are tangential to the surface of the Earth. If the Earth were a perfect sphere without an atmosphere, the radio horizon would be a circle. The radio horizon of the transmitting and receiving antennas can be added together to increase the effective communication range. Radio wave propagation is affected by atmospheric conditions, ionospheric absorption , and the presence of obstructions, for example mountains or trees. Simple formulas that include the effect of the atmosphere give the range as:

Chapter 5 : Non-line-of-sight propagation - Wikipedia

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Radio waves incident upon an obstruction comprising a thin intermediate material are partly reflected at both the incident and exit boundaries and partly absorbed, depending on the thickness. If the obstruction is thick enough the radio wave might be completely absorbed. Because of the absorption, these are often called lossy materials, although the degree of loss is usually extremely variable and often very dependent on the level of moisture present. They are often heterogeneous and comprise a mixture of materials with various degrees of conductor and insulator properties. Such examples are hills, valley sides, mountains with substantial vegetation and buildings constructed from stone, brick or concrete but without reinforced steel. The thicker they are the greater the loss. For example, a wall absorbs much less RF power from a normally incident wave than a building constructed from the same material. Means of achieving non-line-of-sight transmission[edit] Passive random reflections[edit] Passive random reflections are achieved when plane waves are subject to one or more reflective paths around an object that makes an otherwise LOS radio path into NLOS. The reflective paths might be caused by various objects that could either be metallic very good conductors such as a steel bridge or an airplane or relatively good conductors to plane waves such as large expanses of concrete building sides, walls etc. Sometimes this is considered a brute force method because, on each reflection the plane wave undergoes a transmission loss that must be compensated for by a higher output power from the transmit antenna compared to if the link had been LOS. However the technique is cheap and easy to employ and passive random reflections are widely exploited in urban areas to achieve NLOS. Passive repeaters[edit] Passive repeaters may be used to achieve NLOS links by deliberately installing a precisely designed reflector at a critical position to provide a path around the obstruction. However they are unacceptable in most urban environments due to the bulky reflector requiring critical positioning at perhaps an inaccessible location or at one not acceptable to the planning authorities or the owner of the building. However, they have been successfully used in rural mountainous areas to extend the range of LOS microwave links around mountains, thus creating NLOS links. In such cases the installation of the more usual active repeater was usually not possible due to problems in obtaining a suitable power supply. Active repeaters[edit] An active repeater is a powered piece of equipment essentially comprising a receiving antenna, a receiver, a transmitter and a transmitting antenna. The active repeater may simply amplify the received signal and re-transmit it un-altered at either the same frequency or a different frequency. The former case is simpler and cheaper but requires good isolation between two antennas to avoid feedback , however it does mean that the end of the NLOS link at A or C does not require to change the receive frequency from that used for a LOS link. A typical application might be to repeat or re-broadcast signals for vehicles using car radios in tunnels. A repeater that changes frequency would avoid any feedback problems but would be more difficult to design and expensive and it would require a receiver to change frequency when moving from the LOS to the NLOS zone. A communications satellite is an example of an active repeater that does change frequency. The propagation is very low loss and communications over thousands of miles over NLOS links is possible. However, such low frequencies by definition Nyquistâ€"Shannon sampling theorem are very low bandwidth, so this type of communication is not widely used. The transmit beam is directed into the troposphere just above the horizon with sufficient power flux density that gas and water vapour molecules cause scattering in a region in the beam path known as the scatter volume. Some components of the scattered energy travel in the direction of the receiver antennas and form the receive signal. Since there are very many particles to cause scattering in this region, the Rayleigh fading statistical model may usefully predict behaviour and performance in this kind of system. Its relative permittivity or dielectric constant reduces steadily from about 1. Anomalous propagation[edit] The phenomenon described above that the atmospheric refractive index, relative permittivity or dielectric constant gradually reduces with increasing height is on account of the reduction of the atmospheric air density with increasing height. Air density is also a function of temperature, which ordinarily also reduces with increasing height. However, these are only average conditions; local meteorological conditions can create phenomena such as temperature inversion layers where a warm layer of air settles above a cool layer. At the interface between them exists a relatively abrupt change in refractive index from a smaller value in the cool layer to a larger value in the warm layer. The result is that radio waves can propagate well beyond their intended service area with less than normal attenuation. This effect is only apparent in the VHF and UHF spectra and is often exploited by amateur radio enthusiasts to achieve communications over abnormally long distances for the frequencies involved. Temperature inversion and anomalous propagation can occur at most latitudes but they are more common in tropical climates than temperate climates, usually associated with high pressure areas anticyclones. Ionospheric propagation[edit] The mechanism of ionospheric propagation in supporting NLOS links is similar to that for atmospheric refraction but, in this case, the radio wave refraction occurs not in the atmosphere but in the ionosphere at much greater altitudes. The initial discovery that radio waves could travel beyond the horizon by Marconi in the early 20th century prompted extensive studies of ionospheric propagation for the next 50 years or so, which have yielded various HF link channel prediction tables and charts. In the latter half of the twentieth century, alternative means of communicating over large NLOS distances were developed such as satellite communications and submarine optical fiber, both of which potentially carry much larger bandwidths than HF and are much more reliable. Despite their limitations, HF communications only need relatively cheap, crude equipment and antennas so they are mostly used as backups to main communications systems and in sparsely populated remote areas where other methods of communication are not cost effective. However, if it has finite thickness the absorption is also finite and the resulting attenuation of the radio waves may be tolerable and an NLOS link may be set up using radio waves that actually pass through the material. The radio frequencies used, typically a few gigahertz GHz normally passes through a few thin office walls and partitions with tolerable attenuation. After many such walls though or after a few thick concrete or similar non-metallic walls the NLOS link becomes unworkable. Earthâ€”Moonâ€”Earth communication , Meteor burst communications , and Sporadic E propagation are also other methods of achieving communications past the radio horizon. How is positioning accuracy affected by NLOS conditions? However, infringement of this assumption can result in inaccurate positioning data. The NLOS error is always positively biased with the magnitude dependent on the propagation environment.

Chapter 6 : What Is Radio Line Of Sight - Fleeman, Anderson & Bird, Corp.

Line of sight (LoS) is a type of propagation that can transmit and receive data only where transmit and receive stations are in view of each other without any sort of an obstacle between them. FM radio, microwave and satellite transmission are examples of line-of-sight communication.

Chapter 7 : VHF/UHF/Microwave Radio Propagation: A Primer for Digital Experimenters

Tactical Line-of-Sight Radio Army Tactical Radio, Propagation, Line-of-Sight Links, Fading, 82 gation or the fragility of digital transmission systems. This.

Chapter 8 : URC (V2) Line of Sight Transceiver - General Dynamics Mission Systems

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