# MICROWAVE TRANSMISSION LINES AND THEIR PHYSICAL REALIZATIONS pdf

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*Microwave Transmission Lines and Their Physical Realizations AUTHOR: Steven L. March FORMAT: 6 CD-ROMs.*

Uses[ edit ] Microwaves are widely used for point-to-point communications because their small wavelength allows conveniently-sized antennas to direct them in narrow beams, which can be pointed directly at the receiving antenna. This allows nearby microwave equipment to use the same frequencies without interfering with each other, as lower frequency radio waves do. Another advantage is that the high frequency of microwaves gives the microwave band a very large information-carrying capacity; the microwave band has a bandwidth 30 times that of all the rest of the radio spectrum below it. A disadvantage is that microwaves are limited to line of sight propagation; they cannot pass around hills or mountains as lower frequency radio waves can. A parabolic satellite antenna for Erdfunkstelle Raisting, based in Raisting , Bavaria , Germany Microwave radio transmission is commonly used in point-to-point communication systems on the surface of the Earth, in satellite communications , and in deep space radio communications. Other parts of the microwave radio band are used for radars , radio navigation systems, sensor systems, and radio astronomy. Radio waves in this band are usually strongly attenuated by the Earthly atmosphere and particles contained in it, especially during wet weather. The electronic technologies needed in the millimeter wave band are also much more difficult to utilize than those of the microwave band. Wireless transmission of information One-way e. In microwave radio relay, microwaves are transmitted on a line of sight path between relay stations using directional antennas , forming a fixed radio connection between the two points. The requirement of a line of sight limits the separation between stations to the visual horizon, about 30 to 50 miles. Before the widespread use of communications satellites , chains of microwave relay stations were used to transmit telecommunication signals over transcontinental distances. Much of the transcontinental traffic is now carried by cheaper optical fibers and communication satellites , but microwave relay remains important for shorter distances. Antennas must be highly directional high gain ; these antennas are installed in elevated locations such as large radio towers in order to be able to transmit across long distances. Typical types of antenna used in radio relay link installations are parabolic antennas , dielectric lens, and horn-reflector antennas , which have a diameter of up to 4 meters. Highly directive antennas permit an economical use of the available frequency spectrum, despite long transmission distances. Danish military radio relay node Because of the high frequencies used, a line-of-sight path between the stations is required. Additionally, in order to avoid attenuation of the beam, an area around the beam called the first Fresnel zone must be free from obstacles. Obstacles in the signal field cause unwanted attenuation. High mountain peak or ridge positions are often ideal. Production truck used for remote broadcasts by television news has a microwave dish on a retractible telescoping mast to transmit live video back to the studio. Obstacles, the curvature of the Earth, the geography of the area and reception issues arising from the use of nearby land such as in manufacturing and forestry are important issues to consider when planning radio links. In the planning process, it is essential that "path profiles" are produced, which provide information about the terrain and Fresnel zones affecting the transmission path. The presence of a water surface, such as a lake or river, along the path also must be taken into consideration since it can reflect the beam, and the direct and reflected beam can interfere at the receiving antenna, causing multipath fading. Rare events of temperature, humidity and pressure profile versus height, may produce large deviations and distortion of the propagation and affect transmission quality. All previous factors, collectively known as path loss , make it necessary to compute suitable power margins, in order to maintain the link operative for a high percentage of time, like the standard  Hop distance is the distance between two microwave stations [2] Previous considerations represent typical problems characterizing terrestrial radio links using microwaves for the so-called backbone networks: During s microwave radio links begun widely to be used for urban links in cellular network. Furthermore, link planning deals more with intense rainfall and less with multipath, so diversity schemes became less used. Another big change that occurred during the last decade was an evolution toward packet radio transmission. Therefore, new countermeasures, such as adaptive modulation , have been adopted. The emitted power is regulated by norms EIRP both for cellular system and microwave. In the last decade the dedicated spectrum for each microwave band reaches an extreme overcrowding, forcing efforts towards techniques for increasing the transmission capacity frequency reuse, Polarization-division multiplexing , XPIC , MIMO. History[ edit ] Antennas of experimental 1. The receiving antenna background, right was located behind the transmitting antenna to avoid interference. US Army Signal Corps portable microwave relay station,  Microwave relay systems were first developed in World War II for secure military communication. The first experiments with radio repeater stations to relay radio signals were done in by Emile Guarini-Foresio. In an Anglo-French consortium headed by Andre C. A military microwave link between airports at St. After the war telephone companies used this technology to build large microwave radio relay networks to carry long distance telephone calls. It was expected at that time that the annual operating costs for microwave radio would be greater than for cable. There were two main reasons that a large capacity had to be introduced suddenly: Pent up demand for long distance telephone service, because of the hiatus during the war years, and the new medium of television, which needed more bandwidth than radio. Military microwave relay systems continued to be used into the s, when many of these systems were supplanted with tropospheric scatter or communication satellite systems. When the NATO military arm was formed, much of this existing equipment was transferred to communications groups. The typical communications systems used by NATO during that time period consisted of the technologies which had been developed for use by the telephone carrier entities in host countries. The typical microwave relay installation or portable van had two radio systems plus backup connecting two line of sight sites. These radios would often carry 24 telephone channels frequency division multiplexed on the microwave carrier i. Any channel could be designated to carry up to 18 teletype communications instead. Similar systems from Germany and other member nations were also in use. Long-distance microwave relay networks were built in many countries until the s, when the technology lost its share of fixed operation to newer technologies such as fiber-optic cable and communication satellites , which offer a lower cost per bit. By positioning a geosynchronous satellite in the path of the beam, the microwave beam can be received. At the turn of the century, microwave radio relay systems are being used increasingly in portable radio applications. The technology is particularly suited to this application because of lower operating costs, a more efficient infrastructure , and provision of direct hardware access to the portable radio operator. Microwave link[ edit ] A microwave link is a communications system that uses a beam of radio waves in the microwave frequency range to transmit video , audio , or data between two locations, which can be from just a few feet or meters to several miles or kilometers apart. Microwave links are commonly used by television broadcasters to transmit programmes across a country, for instance, or from an outside broadcast back to a studio. Mobile units can be camera mounted, allowing cameras the freedom to move around without trailing cables. These are often seen on the touchlines of sports fields on Steadicam systems. Tropospheric scatter "troposcatter" or "scatter" was a technology developed in the s allow microwave communication links beyond the horizon, to a range of several hundred kilometers. The transmitter radiates a beam of microwaves into the sky, at a shallow angle above the horizon toward the receiver. As the beam passes through the troposphere a small fraction of the microwave energy is scattered back toward the ground by water vapor and dust in the air. A sensitive receiver beyond the horizon picks up this reflected signal. Signal clarity obtained by this method depends on the weather and other factors, and as a result a high level of technical difficulty is involved in the creation of a reliable over horizon radio relay link. Troposcatter links are therefore only used in special circumstances where satellites and other long distance communication channels cannot be relied on, such as in military communications.

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*G. PHYSICAL REALIZATIONS measurement. Perhaps surprisingly, initialization is a signiï¬•cant problem. There are two ï¬•gures of merit: Â¶9. The minimum ï¬•delity with which an initial state can be prepared.*

Share on Facebook Microwave radio signals are electromagnetic waves short wavelengths and high high frequencies between MHz to GHz. About 35 percent of all terrestrial communication is maintained by microwave radio relay systems. There are various types of microwave radio communication systems, operating anywhere between 15 miles to 4, miles, including feeder service or intrastate microwave systems and long-haul microwave systems. Wide shot of a radio antenna at sunset credit: Able to Transmit Large Quantities of Data Microwave radio systems can broadcast large quantities of information because of their high frequencies. Microwave repeaters also give microwave communication systems the ability to transmit data over extremely long distances. A repeater receives the transmitting signal through one antenna, converts it into an electrical signal and then retransmits it again as a microwave signal at full strength. These signals are sent between transmitters and receivers that lie on top of towers. This allows microwave radio systems to transmit thousands of data channels between two points without relying on a physical medium like fiber optics or wire cables. Video of the Day Advantage: Relatively Low Costs Microwave communication systems have relatively low construction costs compared with other forms of data transmission, such as wire-line technologies. A microwave communication system does not require physical cables or expensive attenuation equipment devices that maintain signal strength during transmission. Mountains, hills and rooftops provide inexpensive and accessible bases for microwave transmission towers. Solid Objects Microwave radio systems do not pass through solid objects. This can be problematic in cities with a lot of tall buildings or mountainous regions if you want to send a signal from one end of the city to the other. There are ways to work around this, like erecting repeaters between two towers if an object is blocking them. Signals can also be bounced off of solid objects and even the ionosphere. It is even possible to bounce microwaves off of the moon, in earth-moon-earth communications known as moon bouncing. Subject to Electromagnetic and Other Interference Electromagnetic interference, or EMI, can obstruct or degrade the performance of microwave signals. Electric motors, electric power transmission lines and wind turbines can all emit EMI that disrupts microwave communication. Wind turbines, for example, scatter and diffract TV, radio and microwave signals when placed between signal transmitters and receivers. Microwave radio communication can also be degraded by heavy moisture in the atmosphere, snow, rain and fog, in a phenomenon known as rain fade.

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Waveguides Chapter 14 - Transmission Lines A waveguide is a special form of transmission line consisting of a hollow, metal tube. The tube wall provides distributed inductance, while the empty space between the tube walls provide distributed capacitance: Figure below Wave guides conduct microwave energy at lower loss than coaxial cables. Waveguides are practical only for signals of extremely high frequency, where the wavelength approaches the cross-sectional dimensions of the waveguide. Below such frequencies, waveguides are useless as electrical transmission lines. When functioning as transmission lines, though, waveguides are considerably simpler than two-conductor cablesâ€”especially coaxial cablesâ€”in their manufacture and maintenance. In a sense, all transmission lines function as conduits of electromagnetic energy when transporting pulses or high-frequency waves, directing the waves as the banks of a river direct a tidal wave. However, because waveguides are single-conductor elements, the propagation of electrical energy down a waveguide is of a very different nature than the propagation of electrical energy down a two-conductor transmission line. All electromagnetic waves consist of electric and magnetic fields propagating in the same direction of travel, but perpendicular to each other. Along the length of a normal transmission line, both electric and magnetic fields are perpendicular transverse to the direction of wave travel. This mode of wave propagation can exist only where there are two conductors, and it is the dominant mode of wave propagation where the cross-sectional dimensions of the transmission line are small compared to the wavelength of the signal. Figure below Twin lead transmission line propagation: At microwave signal frequencies between MHz and GHz , two-conductor transmission lines of any substantial length operating in standard TEM mode become impractical. It is at these high frequencies that waveguides become practical. Whichever field remains transverse to the direction of travel determines whether the wave propagates in TE mode Transverse Electric or TM Transverse Magnetic mode. Many variations of each mode exist for a given waveguide, and a full discussion of this is subject well beyond the scope of this book. Signals are typically introduced to and extracted from waveguides by means of small antenna-like coupling devices inserted into the waveguide. Sometimes these coupling elements take the form of a dipole, which is nothing more than two open-ended stub wires of appropriate length. Figure below Stub and loop coupling to waveguide. Figure below below Klystron inductive output tube. Just as transmission lines are able to function as resonant elements in a circuit, especially when terminated by a short-circuit or an open-circuit, a dead-ended waveguide may also resonate at particular frequencies. When used as such, the device is called a cavity resonator. Inductive output tubes use toroid-shaped cavity resonators to maximize the power transfer efficiency between the electron beam and the output cable. To this end, cavities with movable plates, screws, and other mechanical elements for tuning are manufactured to provide coarse resonant frequency adjustment. If a resonant cavity is made open on one end, it functions as a unidirectional antenna. The following photograph shows a home-made waveguide formed from a tin can, used as an antenna for a 2. The coupling element is a quarter-wave stub: Figure below Can-tenna illustrates stub coupling to waveguide. Although this can is of cardboard paper construction, its metallic inner lining provides the necessary conductivity to function as a waveguide. Some of the cans in the background still have their plastic lids in place. The plastic, being nonconductive, does not interfere with the RF signal, but functions as a physical barrier to prevent rain, snow, dust, and other physical contaminants from entering the waveguide. They are practical only for signals of extremely high frequency, where the signal wavelength approaches the cross-sectional dimensions of the waveguide. Wave propagation through a waveguide may be classified into two broad categories: TE Transverse Electric , or TM Transverse Magnetic , depending on which field electric or magnetic is perpendicular transverse to the direction of wave travel. Wave travel along a standard, two-conductor transmission line is of the TEM Transverse Electric and

Magnetic mode, where both fields are oriented perpendicular to the direction of travel. TEM mode is only possible with two conductors and cannot exist in a waveguide. A dead-ended waveguide serving as a resonant element in a microwave circuit is called a cavity resonator.

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*Microwave measurements involve transmission circuit and these are described in terms of their If a transmission line is not matched then part of.*

The transmission lines which has more than one conductor are called as Multi-conductor lines. Co-axial Lines This one is mostly used for high frequency applications. A coaxial line consists of an inner conductor with inner diameter d, and then a concentric cylindrical insulating material, around it. This is surrounded by an outer conductor, which is a concentric cylinder with an inner diameter D. This structure is well understood by taking a look at the following figure. The fundamental and dominant mode in co-axial cables is TEM mode. There is no cutoff frequency in the co-axial cable. It passes all frequencies. However, for higher frequencies, some higher order non-TEM mode starts propagating, causing a lot of attenuation. The width of the ground plates is five times greater than the spacing between the plates. The thickness of metallic central conductor and the thickness of metallic ground planes are the same. The following figure shows the cross-sectional view of the strip line structure. The fundamental and dominant mode in Strip lines is TEM mode. Micro Strip Lines The strip line has a disadvantage that it is not accessible for adjustment and tuning. This is avoided in micro strip lines, which allows mounting of active or passive devices, and also allows making minor adjustments after the circuit has been fabricated. This can be understood by taking a look at the following figure, which shows a micro strip line. Micro strip lines are of many types such as embedded micro strip, inverted micro strip, suspended micro strip and slotted micro strip transmission lines. In addition to these, some other TEM lines such as parallel strip lines and coplanar strip lines also have been used for microwave integrated circuits. Other Lines A Parallel Strip line is similar to a two conductor transmission line. It can support quasi TEM mode. The following figure explains this. A Coplanar strip line is formed by two conducting strips with one strip grounded, both being placed on the same substrate surface, for convenient connections. A Slot line transmission line, consists of a slot or gap in a conducting coating on a dielectric substrate and this fabrication process is identical to the micro strip lines. Following is its diagrammatical representation. A coplanar waveguide consists of a strip of thin metallic film which is deposited on the surface of a dielectric slab. This slab has two electrodes running adjacent and parallel to the strip on to the same surface. All of these micro strip lines are used in microwave applications where the use of bulky and expensive to manufacture transmission lines will be a disadvantage. A waveguide that is not entirely enclosed in a metal shielding, can be considered as an open waveguide. Free space is also considered as a kind of open waveguide. An open waveguide may be defined as any physical device with longitudinal axial symmetry and unbounded cross-section, capable of guiding electromagnetic waves. They possess a spectrum which is no longer discrete. Micro strip lines and optical fibers are also examples of open waveguides.

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*The transmission line section approximates the desired behavior within a narrow range of frequencies around the frequency at which the electrical length of the line is t.*

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*Assume we have a transmission line in which air separated the two perfect conductors. Assume the impedance of the line is 50 ohm, phase constant is 20 (rad/m) and the operating frequency is MHz.*

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