Requirements for Sharing Sites in Terms of Microwave Radiolinks

Future expansion of wireless services will require more sharing of towers and hilltop sites

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Presently, many different types of terrestrial radio systems are providing communications directly to users. Examples of such systems include paging, analog and digital trunking such as iDEN™, two-way mobile radios, PCS, WLL, and cellular telephone systems such as NMT, TACS, AMPS, EAMPS, NAMPS, GSM, PHS, CDMA and TDMA.

Despite the widespread deployment of fiber optic systems, there is still a huge demand for the interconnection of sites using digital microwave radios (DMRs), not just in rural areas but also in cities. Reasons for this demand include lack of existing cable ducts and the high cost of new ones, the ease of installing radiolinks, their rapid deployment and expansion, high availability and the ease of routing reconfiguration. Considering these factors, interference is an issue becoming more important for microwave system engineers.

The necessity of sharing sites is expanding, mainly because of the high cost of the necessary infrastructure, such as poles or towers, supporting structures like masts, grounding, real estate renting, shelters, air conditioning, power supply and fire protection systems. However, when sharing sites it is essential to avoid harmful interference, not only on radio frequency (RF) systems but also on microwave (MW) radio systems.

This paper discusses some useful guidelines to prevent damaging interference among microwave radiolinks in order to guarantee maximum usage of towers and poles (in terms of the number of microwave parabolic dishes that can be installed in the same physical location at the same time).

Some useful definitions

Within the scope of this article, the following definitions will be useful:

Site — A general term referring to a base station or a microwave repeater.

PoP (Point of Presence) — A site with at least one MW system installed (i.e., a terminal station with only one MW antenna in nonspace diversity systems). In a large network, the majority of stations normally have two directions (i.e., two antennas, one for each direction, forward and reverse). Note that, in this context, the word "site" does not always refer to a PoP, since a PoP always has a MW radio while a site may have or not. For instance, a site can be linked via fiber optics, HDSL (High bit-rate Digital Subscriber Line) modem or even satellite.

Requesting company — the company that requests the microwave sharing of a PoP.

Requested company — the company that receives a request for sharing of a PoP.

Local end — the PoP to be shared

Remote end — the other PoP linked to the local end via one or more MW radio links.

Objectives and presupposition

The main objective of this article is to establish technical criteria for sharing sites from a microwave point of view. The guidelines are primarily oriented for the 15-, 18- and 23-GHz bands, as these are the most frequent bands used by cellular-type TELCOs when they are interconnecting sites by means of digital microwave radios.

However, the same methodology is also valid for other microwave frequency bands, including the 11- (SDH STM-1), 26- or 38-GHz bands. According to IEEE, waves between 30 GHz and 300 GHz are termed millimeter waves instead of microwaves.

As an essential presupposition, we will

assume the requested and/or requesting company has a versatile software package, able to perform accurate microwave interference, performance and availability calculations, with a specialized and well-skilled technical team as well as a superb radiolink and equipment database.

The main purpose of the study is to ensure that the installation of the requesting company's radiolink will not substantially degradate the existing radiolinks at the PoP and near it. The second purpose is to ensure that the requested company can authorize new sharings after this.

The allowed degradation casued by the new radiolink must be defined by the requested company according to its interference/availability criteria. Suppose we have an 18-GHz sharing. If the requested company has an objective of .02 percent of unavailability per annum per link (due to propagation only; mainly rain), this objective cannot be exceeded with the sharing addition. From the point of view of the requested company, the degradation caused by the new radiolink must keep all of the individual unavailabilities of all other radiolinks below the desired value (.02 percent per annum per link in this example). This is a sine qua non condition for the approval of the sharing. It is important to note that this condition is fundamental but not sufficient for the approval. Infrastructure and legal questions must always be taken into account.

Technical documentation

For each sharing, the requesting company always has two distinct possibilities. The first is to provide the complete microwave design for the link, proving to the requested company that microwave interference will be under acceptable limits. This is, of course, the preferable option, although it is a complex subject for most companies, due to lack of specialized personnel, design data and software.

The second possibility is that the requesting company sends all the technical information to the requested company, which then completes the frequency coordination. If frequency coordination is acceptable, sharing is feasible. Otherwise, some design modifications must be made in order to approve the sharing.

Notice that, in the second option, only the frequency coordination will be completed by the requested company (and, even so, between its own radiolinks and the shared radiolinks). Performance calculations and frequency coordination with other companies and systems (like satellites and radars) are always the responsibility of the radiolink owner.

For instance, radio-relay systems operating in the 6-GHz band may suffer interference from uplinks of C-band satellites, and radio-relay systems operating in the 4-GHz band may cause interference in downlinks of C-band satellites. Thus, the installation of radiolinks operating at 6 GHz or 4 GHz requires frequency coordination with C-band satellite systems.

In addition, it is the responsibility of the requesting company to suggest the antenna location (based on the determination of antenna heights and reflection points) and to investigate possible interference with existing flying fields and airports. It is possible, for example, that there is no physical space for a new antenna at the correct bearing and height on the tower.

For the second possibility, the requesting company must provide the following technical information and infrastructure data:

The remote end — The remote end must be provided with its name and full address.

The PoP to be shared — The PoP (local end) where the microwave sharing will occur must be provided.

The positioning coordinates of the remote end — The geographical (GEO) coordinates (latitude and longitude) are typically expressed in the sexagesimal form (i.e., degrees, minutes and seconds). Sometimes the requesting company presents its coordinates in UTM (Universal Transverse Mercator) format, or in values expressing north or east, for example. When the positioning coordinates are obtained from topographical charts, they are normally expressed in UTM format. Usually in this case, it is necessary to convert from UTM to GEO before inserting these values in the software package (the software typically works with latitude and longitude only).

GEO		UTM
Latitude (=ϕ)	$\Rightarrow$	Northing Value (=N)
Longitude (=λ)	$\Rightarrow$	Easting Value (=E)

The accuracy of the coordinates must be within 50 meters (±164 ft) of the exact, or ideal, location (with an error circle with a radius of 50 m). This is the minimum acceptable accuracy for positioning coordinates to be used for microwave frequency coordination. It is essential to be aware of the horizontal or planimetric reference datum (or HRD) since the geographical coordinates change when planimetric datum changes.

Geographical coordinates for a PoP may read, for example:

Site: Icarahy
Latitude = 22° 35' 23.6" S
Longitude = 45° 14' 10.2" WGr
HRD = SAD-69

where S stands for south (N for north) and WGr stands for west of Greenwich (EGr for East of Greenwich). SAD-69 is an acronym for South American Datum 1969 and is a widely-used horizontal datum for South America. In North America, we have for example, NAD

83 (an acronym for North American Datum 1983).

There are numerous other horizontal data such as WGS-84 (World Geodetic Datum 1984), Yacare (South America), Tokyo (Japan), Djakarta (Indonesia), Easter Island (Pacific Ocean) and WGS-72 (World Geodetic Datum 1972). The right choice of the horizontal datum is crucial for good path calculations. We do not pay particular attention here to the positioning coordinates of the local end because they are obviously known by the requested company (after all, it is its own location).

Altitude and height (expressed in meters or feet) — Altitude is measured with reference to the mean sea level (MSL), and height is measured with reference to the soil or ground level. In this application, altitudes are known as AMSL (above mean sea level) and heights as AGL (above ground level). It is essential to inform the vertical or altimetric reference datum (or VRD) with the altitude since altitudes change when the vertical datum changes.

Height measures the vertical distance from antenna port to the ground. Presently, the official vertical datum adopted in Brazil is the tidal station of "Maregrafo de Imbituba" in Santa Catarina state, south Brazil.

Equipment configuration — Equipment configuration can be either fully non-protected (both transmitters, and receivers) or protected. There are several types of protection schemes and diversity arrangements, including (1+1) hot-standby, frequency diversity, quadruple diversity, space diversity, and so on.

Transmit frequencies (expressed in GHz) — Transmit frequencies include F Tx Rem, which is the remote end transmit frequency, and F Tx Loc, which is the local end transmit frequency.

Link polarization — The radiolink polarization must be of linear type, either horizontal (H-pol) or vertical (V-pol). Since V-pol is superior to H-pol (as a protection against rain effects), it is possible that the requested company will reserve V-pol, at the local end, for its own links. In the case of helical antennas (see next section) circular polarization appears (either left-hand or right-hand).

Antenna data — This includes model and manufacturer (e.g., VHP4-142 ANDREW); diameter (expressed in meters or feet); and mid-band gain (expressed in dBi or dBd).

Terrestrial microwave antenna systems use, in most cases, parabolic antennas (and, for this type of aerial, diameter is very useful). However, other types of antennas may be utilized like horns and, in the beginning of microwave frequencies, Yagis and helicals.

There is a theoretical controversy on the beginning of the microwave frequency band. Some authors claim that this occurs at 900 MHz, others at 500 MHz, 300 MHz (coinciding with the beginning of UHF band) and even at 3 GHz (the end of the UHF band or the beginning of the SHF band).

For parabolic antennas, the model frequently provides diameter information. The following examples are taken from a manufacturer's catalogue.

Model = UHX10-59W	d = 10 ft (or 3,0 m)
Model = KP8-25B	d = 8 ft (or 2,4 m)
Model = VHP1-570	d = 1 ft (or 0,3 m)

Normally, for microwave bands, antenna gains are measured in dBi (decibels over an isotropic radiator) and not in dBd (decibels over a half-wave dipole). The unit dBd occurs more frequently in VHF (Very-High Frequency) and UHF (Ultra-High Frequency) radio systems instead of SHF (Super-High Frequency) and EHF (Extremely-High Frequency). The relationship between the two units, dBi and dBd, is expressed as follows:

$$X\ (\text{dBi}) = Y\ (\text{dBd}) + 2.15$$

Other data such as the front-to-back ratio (FBR), half-power beamwidth angle (HPBW) and cross-polarization discrimination (XPD0) can be extracted directly from the RPEs diagrams (see the next section).

Radiation pattern envelopes (RPE) — Four RPEs are always needed when analyzing the behavior of microwave antennas: two parallel envelopes (named HH and VV) and two crossed envelopes (named HV and VH). RPEs must be sent in tabulated format as well as graphical format for checking. These acronyms mean:

- HH — The response of a horizontally polarized antenna port (H-port) to a horizontally polarized microwave radio signal.
- VV — The response of a vertically polarized antenna port (V-port) to a vertically polarized microwave radio signal.
- HV — The response of a horizontally-polarized antenna port to a vertically-polarized microwave radio signal.
- VH — The response of a vertically polarized antenna port to a horizontally polarized microwave radio signal.

Transmit output power (expressed in dBm) — It is always necessary to define the interface related to the transmit output power value (e.g., antenna port or radio port). Without this information, it is impossible to obtain the real gain/loss block diagram of the radio equipment.

If the radio includes a booster or a high power amplifier (HPA), this issue must be considered in the transmit output value. The same can be said for automatic transmitter power control (ATPC). In addition, if transmit output power can be reduced (e.g., –3 or –6 dB below its nominal value), one must also be aware of it to reduce interference levels to acceptable limits.

Bit rate (expressed in Mbit/s or megabits per second)— The most correct approach for bit rates is the use of the gross bit rate (GBR) or the aggregate bit rate (ABR). GBR is the final result of the bit rate after inserting the forward error correction (FEC), voice frequency channel, data channel and control/monitoring channel via the radio equipment.

Modulation scheme — We have, for example, O-QPSK (offset quadrature phase-shift keying), 16-QAM (16-states quadrature amplitude modulation), 32-QAM, 64-QAM, 128-QAM, 4-FSK (four-level frequency shift keying) or 4D-TCM (Four-Dimensional Trellis Coded Modulation).

Receive noise (expressed in dB) — Receive noise is measured at the receiver input port.

Receive thresholds for a 10E–3 and 10E–6 BER (expressed in dBm) — The receive threshold is the receive power level normally at the antenna interface (equal to antenna port) for a given BER (bit error rate). Receive thresholds depend on the equipment configuration and bit rate capacity. This is 2E1, 4E1, 8E1, 16E1 in CEPT hierarchy (Conférence Européenne des Administrations des Postes et des Télécommunications). Usually, we use the BER 10E–3 and 10E–6. Sometimes the receive threshold for a 10E-10 BER, or for other values somewhat close to this, is also provided.

Transmit spectrum mask (spectrum occupancy) — All filters and devices (circulators, isolators, transitions, elbows) must be right in the beginning of the waveguide (elliptical, circular or rectangular) or coaxial cable in lower frequencies. They must be provided in the form of a decibel versus frequency offset curve. The offset represents the positive or negative frequency offset from the carrier frequency (that is to say, $f_0 + \Delta f$ and $f_0 - \Delta f$), and is generally expressed in MHz. In terms of unwanted emissions (spurious and out-of-band), the equipment must meet the appropriate specifications (like, in the U.S., FCC Part 101 Section 101.111, emission limitations).

Receive frequency response from RF section to BB (baseband) section — The receive chain (RF + IF + BB) filtering is composed by three curves, namely the receive RF filter frequency response curve, the receive IF filter frequency response curve and the receive BB filter frequency response curve. All three curves show the filter response (in dB) versus the frequency offset (in MHz).

Attenuator (expressed in dB) — When a fixed in-line attenuator (pad) is used, it is mandatory to recognize whether the attenuator belongs to the transmit path only, to the receive path only or to both paths (transmit and receive one).

Additional Losses (expressed in dB) — Additional losses are divided into two parts. Both parts include the portion between the antenna interface and the radio interface. The antenna interface is located between the antenna and the transmitting line (waveguide or coaxial cable). The radio interface is located between the radio equipment and the transmitting line.

The antenna interface consists of the transmit path losses and the radio interface consists of the receive path losses. Depending on the situation, it is possible that there are some differences between these two losses. Overall additional losses are equal to the summation of losses in the transmission line, flex-twists (or jumpers for coaxial), hybrid devices, switches, circulators, isolators, straight sections, flange adapters, waveguide to coaxial adapters, taper transitions, 90 degree E-Plane and H-Plane elbows, power dividers and the radome.

Infrastructure data for microwave sharing

Supply of power — Power consumption depends on the equipment configuration. The best choice is the use of guaranteed maximum wattages for each unit and, as a direct consequence, for the radio equipment as a whole. The addition of protection schemes or diversity arrangements, service channels, HPAs (boosters) and other optional electrical units, such as relay interface modules, increase radio power consumption.

Power supply main specifications include operating currents, DC input voltage range and polarity, when applicable (some equipment uses positive or negative ground). This is typical with the use of 48 VDC systems.

Circuit breakers are the responsibility of the requesting company. The number of breakers is a function of the radio configuration. Generally, one single indoor unit needs one breaker; two indoor units need two breakers. If available, the battery noise level mask must be provided, showing noise level in the vertical axis, in volts RMS (root mean square) versus noise frequency in the horizontal axis (in Hz).

It is a good engineering practice to install surge protectors on data/signal lines, telephone lines, coaxial lines and AC lines. It is mandatory that coaxial lines entering shelters or houses have their own protections (one per coax).

Commonly, we use gas tube surge protectors for microwaves by virtue of their low insertion loss, low VSWR (voltage standing wave ratio), easy installation and wideband behavior. Coaxes carrying signals between outdoor and indoor radio units operate not only in baseband, including DC for powering the outdoor unit, but also in intermediate frequencies like 70 or 140 MHz and even higher values.

This broadband behavior prohibits the use of quarter-wave stub protectors for microwave applications since they can not pass DC signals and their frequency bands are generally incompatible with those bands travelling across the IDU to the ODU coaxial.

Dimensions and weights for units, antennas, coaxes or waveguides — It is essential to have access to information on physical dimensions (height, width and depth) and weight, both for indoor (IDU) and outdoor (ODU) units. Sometimes ODU is known as a radio unit (or a radio frequency unit, RFU), and IDU is known as a signal unit (or a signal processing unit, SPU). Dimensions are generally expressed in millimeters (mm) or inches (in), and weights are expressed in kilograms (kg) or pounds (lb). At this point it is appropriate to say that, strictly speaking in terms of physics, mass and weight are different physical quantities (so, they are measured by different physical units, i.e., kilograms for mass and newtons for weight in the International System of Units — S.I.). In this case, we are speaking about mass, not weight, as mass is often confused with weight and vice-versa.

The two previously-mentioned

units are related by:

1 in = 25.4 mm (exact)

1 kg ≈ 2.2 lbm

where the suffix m (in lbm) stands for "mass," emphasizing its opposition to force (pound-mass instead of pound-force).

The requested company often limits the diameter of the parabolic dish in its own site in order to maximize physical space occupation and to reduce wind loading (in order to achieve this, a moulded radome may be needed). It is very rare but it is possible that there are restrictions on antenna paints, radome colors (gray, aviation orange and white) and radome types (moulded x planar).

Usually the largest acceptable diameter is 4 feet (or 1.2 meters). If an antenna with larger diameter (e.g., 8 ft/2.4 m or 10 ft/3.0 m) is needed, it must be installed in the remote end. The presence or absence of antenna shielding is also important since the overall physical dimensions and weight increase because of cylindrical shielding.

Some mechanical characteristics of the coaxial cable interconnecting IDU and ODU or waveguide are also important. They include dimensions over jacket or outer diameter (in millimeters or inches), distributed weight (in kgf/m or lbf/ft), and minimum bending radius (in millime-

Environmental requirements

1. Ambient Temperature Ranges (in °C or °F)
   - 1.1 Transportation and Storage
   - 1.2 Full Operational
   - 1.3 Operational but Degraded (e.g., presence of signal errors)
2. Percent Relative Humidity
   - 2.1 Operational
   - 2.2 Transportation
3. Altitude (above Mean Sea Level)
   - 3.1 Operational
   - 3.2 Transportation
4. Wind Effects
   - 4.1 Axial Force (= F_A)
   - 4.2 Side Force (= F^S)
   - 4.3 Twisting Moment (= M_T)
5. Hail and Snow
6. Ice Accumulation on Outdoor Parts
7. Aerial Pollutants and Particles
8. Dust and Sand Storms
9. General EMI (Electromagnetic Interference)
10. Lightning
11. Vibration
    - 11.1 Indoor (installed units)
    - 11.2 Transit (packaged units)
12. Shock (drop / bump)
    - 12.1 Transit
    - 12.2 Handling
13. Earthquakes

ters or inches).

For waveguides, the last specification is the minimum bending radius (E plane and H plane), with and without rebending. This waveguide is not the flex-twist section used in 15-, 18- or 23-GHz systems, but a waveguide for lower frequencies (e.g., 4, 5, 6, 7, 8 or 11 GHz), making the connection from the indoor branching to the outdoor antenna, generally by dozens of meters.

For coaxial cables interconnecting IDUs and ODUs (operating in intermediate frequency IF or baseband BB) the maximum acceptable length is vital information for the installation. Usually, the maximum length is about 300 meters (or 984 feet) due to electrical limitations of the coaxial cable.

Finally, coaxes or waveguides must be installed inside protection ducts (of iron or some polymeric material like polyvinyl chloride-PVC). When the environment is hazardous, due to presence of chemicals, explosive atmospheres, corrosive environments, risk of shock, or there are a lot of T1/E1 signals travelling across the line (such as STM-0 or STM-1), it is a good approach to seek physical protection. The duct can also act as an obstacle against vandalism, the influence of ultraviolet rays, water penetration and fire, thus preserving the cable(s) inside it.

Supplemental installation requirements — If an additional inside rack is needed, do not forget to inquire about rack size. Is the access necessary to the back and/or to the front of the equipment? This answer will determine, for example, the minimum distance from the wall to the back of the rack. Sometimes the IDU must be installed as a desktop unit instead of using a rack (this can occur when there is no physical space for a new rack unit and the existing ones are fully populated).

Be careful when installing rooftop mounts. There can be serious impermeabilization problems. A concrete base for the rooftop mast largely reduces this risk. Typically the mast is 2 meters high and its outer diameter is a function of the antenna dimensions and type (shielded versus unshielded, parabolic versus Yagi or helical, solid versus grid, radomized versus unradomized), as well as the associated hardware.

Table 1 shows common pipe outer diameters versus parabolic diameters for microwave antennas. The dimensions of the concrete bases are

Pipe Outer Diameter (inches)	Antenna Diameter (inches)
4	1.2 or 1.8
3 or 4	0.6
2, 2.4, 3 or 4	0.3

▲ **Table 1. Common pipe outer diameter versus parabolic diameters for microwave antennas.**

also a function of the antenna diameter and type.

Next to the outdoor unit, a 110/220 VAC shielded socket and an illumination lamp are very useful. Always have them, unless expressly forbidden.

Another issue is the pressurization system for waveguides. It demands physical space and electric power for the pressurization equipment (dehydrators, distribution panels, gas distribution manifolds, line monitors, extra tanks).

For pressurization equipment, there are basically two types of shelves: a wall shelf and a rack shelf. The wall shelf, of course, becomes attached to a wall and the rack shelf to a 19-inch rack. Sometimes, we use a floor stand for the dehydrator and the regulating tank.

It is important to remember to never attach a pressurization equipment directly to a radio-populated rack unless there is some kind of vibration attenuation scheme, since vibration reduces the lifespan of the electronic equipment.

Some additional technical remarks

If the radio uses FEC (forward error correction) and the FEC is enabled, it must be considered when informing receiving thresholds due to FEC coding gain. A controversial issue is the use of typical or guaranteed values when talking about receiving thresholds, noise figures, transmit output powers, wattages, and general losses. The recommended procedure is to provide both values for a full technical analysis.

When the design is completed by the requesting company, it is important to declare what kind of values were used in the calculations. Two calculations (the first one using typical values and the second one using guaranteed values) must be provided to ensure that there will be no problems with the sharing.

It is also important to clearly define the rules of working/accessing the local end in order to perform actions of operation and maintenance. These would include working hours, who is qualified to access, what kinds of jobs may be done without previous authorization, responsibilities of both parts, procedures in emergency situations, contact people and phones. ■

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