Or,
$$r_2 = 1.414\, r_1$$

Or,
$$r_2 / r_1 = 1.414 \tag{7.10}$$

Step 7. *Let the initial coverage area be A_1 and the new coverage area be A_2. As we know that the coverage area (circular or hexagonal) is directly proportional to square of the radius,*
$$A_2 = (r_2 / r_1)^2\, A_1$$

Step 8. *Using Eq. (7.10), we get $A_2 = (1.414)^2\, A_1$*

Hence,
$$A_2 = 2\, A_1$$

Comments on the results Hence it is proved that when the minimum acceptable received signal power is reduced by 6 dB (or four times), the cell coverage area is doubled for the same cell-site transmitted power and all other factors remaining unchanged.

Wireless repeaters or signal enhancers are often used to extend the coverage area. Repeaters are usually bi-directional in nature, and simultaneously send signals to and receive signals from a serving cell-site. Wireless repeaters may be installed anywhere and are capable of repeating the complete allocated cellular frequency band. Upon receiving signals from a cell-site forward link, the repeater amplifies and reradiates the cell-site signals to the specific extended coverage area.

7.2 COVERAGE HOLE FILLERS AND LEAKY FEEDERS

Coverage hole is an area within the radio coverage footprint of a wireless communication system in which the received RF signal level is below the specified threshold value. Coverage holes, also called *weak received signal spots*, are usually caused by physical obstructions such as buildings, hills, dense foliage as well as hard-to-reach areas such as within buildings (indoor), or in valleys or in tunnels. Because the earth is not flat, many coverage holes are created during transmission of radio signals.

The radio coverage is sometimes blocked in the outdoor wireless network applications which contain high buildings, hills and tunnels, and thus shadow regions are created. It is most desirable to fill in these coverage holes. The received signals are required to be extended by simple means into these coverage hole areas. Deploying a new cell-site in this area could be one possible solution but it is not only expensive, but also requires new channel assignment or rearranging the frequency plan. So it may not be economically justifiable from the revenue point of view from that area which may still be strategically important.

Facts to Know!

In the deployment of any wireless communication network, the radio coverage provided by any given cell-site does not cover 100% locations within the cell boundary, determined by the minimum acceptable received signal levels.

Facts to Know!

The repeater does not add capacity to the system. It simply serves to reradiate the received signal into specific coverage-hole locations.

Among the various techniques available for filling the coverage holes such as wireless enhancers or repeaters (wideband and channelised), passive reflectors, diversity receivers, and cophase combiners (feedforward and feedback), wireless repeaters can provide the simplest and cost-effective solution to reradiate the amplified signal so as to reach the coverage hole areas. Unfortunately, the received noise and interference is also reradiated by the repeater on both the forward and reverse link. Therefore, care must be taken to properly place the repeaters, and to adjust the various forward and reverse-link amplifier levels and antenna patterns. In practice, particularly in tunnels or high-rise buildings, directional antennas or distributed antenna systems are connected to the inputs or outputs of repeaters for localised weak-spot coverage.

By modifying the coverage of a serving cell by using wireless repeaters, a service provider is able to dedicate a certain amount of the cell-site's traffic for the areas covered by the repeater. The two physical considerations for a successful repeater deployment are isolation and line-of-sight conditions. There must be sufficient isolation between the donor antenna and the coverage antenna to prevent feedback oscillation for on-frequency repeaters where the transmitted frequency is the same as the received frequency. In order to meet this requirement, the two antennas — the donor antenna and the coverage antenna — must be physically separated from each other. This physical separation can be realised if

- there is a tower of sufficient height to separate the antennas vertically while pointed in opposite directions—one towards the actual cell-site transmitter and another towards the coverage hole region,
- the antennas are mounted on separate masts with sufficient horizontal separation and pointed in opposite directions as stated above, or
- there is a physical structure such as a building that can provide the needed physical isolation when the antennas can be mounted on opposite sides of the building.

At the repeater location, there must be line-of-sight condition to both the coverage hole area and the desired donor cell-site. It is desirable that the downlink signal from the repeater must be strong enough to be received by the mobile subscribers located in the coverage hole region while the receiver sensitivity of repeater plus that of the cell-site must be sufficient enough to process the signal received from the mobile subscribers.

Figure 7.1 illustrates deployment of the repeater with two different directional antennas mounted on the same tower, one in the direction of the main cell-site and another in the direction of a mobile operating in a coverage hole region.

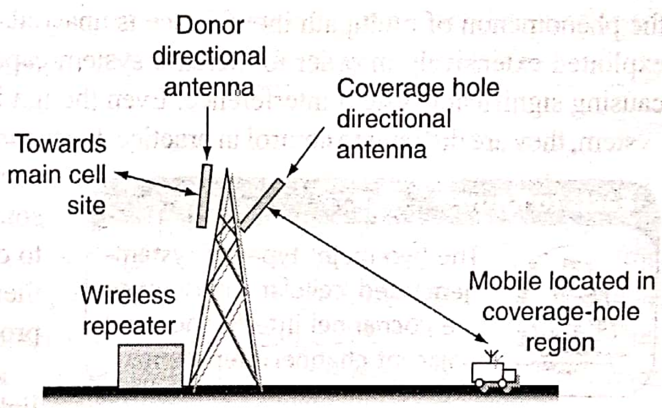

Fig. 7.1 *Illustration for deployment of wireless repeater*

One of the main concerns is that there is overlap between the repeated signal and the primary cell-site signal. The repeated signal has significant added delay. In some cases, it is important to limit the coverage antenna pattern to the area needed and minimise the overlap. If the undesired signal received by the donor directional antenna is transmitted back to the cell-site, cochannel and adjacent-channel interference may occur. For shadow areas such as behind the hills or inside tunnels, this is generally not a problem. Otherwise, an alternative way is to use a high-gain donor antenna to bring in the signal from a neighbour cell. In this case, the mobile subscribers located in coverage-hole regions would hand-off to the neighbour cell in the repeater coverage area and there would be no interference.

Instead of using a wideband enhancer, a channelised enhancer can be effectively deployed which would amplify only the selected channels. Geographic terrain contour should be considered in proper installation of a channelised enhancer. The separation between two antennas at the enhancer is very critical. If this separation is inadequate, the signal from the coverage antenna can be received by the donor antenna or vice versa. This may result in jamming of the system instead of filling the coverage hole. Likewise, the distance between the enhancer location and the serving cell-site should be as minimum as possible to avoid spread of radiations into a large area in the vicinity of the serving cell-site and beyond.

Leaky Feeders In some areas such as in tunnels, underground garages, coal mines or within a cell of less than 1-km radius, leaky-feeder techniques provide adequate coverage with minimum interference. The most popular types of leaky feeders are

- Leaky waveguide or fast-wave antenna
- Leaky coaxial feeder cable

In leaky waveguides, only the fractional energy will be leaking constantly through the opening slots (apertures) of the waveguide structure supporting $\lambda g > \lambda c$, where λg is the wavelength of the transmitted waveguide and λc is the wavelength of the transmitted signal in free space. The *leakage rate* is a function of position of the slot in the waveguide. The radiation pattern of a leaky waveguide can serve a larger area along the waveguide. These are generally used above 3 GHz.

Leaky cables are easily implemented in the tunnels because their energy is confined within the tunnel. Leaky coaxial feeder cables are used at frequencies below 1 GHz because the cable loss is 6 dB/100 m only. The RF powers cannot exceed a maximum of 500 mW in order to prevent any inflammatory sparks for safety considerations. The leaky feeder is characterised by transmission and coupling losses. For proper operation of a leaky coaxial feeder cable, use of high-coupling loss cables near the transmitter is recommended as little energy will leak out and thus have low-transmission loss.

Facts to Know!

Low temperature and snow accumulation around slots causes an increase in transmission loss. Periodic spacing of slots along the leaky coaxial feeder cable causes the intensive radiation pointing to a specific direction.

7.3 SYSTEM PARAMETERS TO REDUCE INTERFERENCE

In a wireless communication environment, no matter whether the signal is transmitted outdoors or indoors, the phenomenon of multipath interference is unavoidable. In a cellular system network, the frequency reuse is exploited extensively in order to increase system capacity by efficient use of allocated RF spectrum, thereby