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A conceptual method for the representation of loss of broadcast coverage

BT Series

Broadcasting service
(television)

International Telecommunication Union

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REPORT ITU-R BT.2248

A conceptual method for the representation of loss of broadcast coverage

1 Introduction

Broadcasters are used to assessing interference probability and coverage loss as a consequence of interference sources that are external to the planned broadcast coverage area. However, the introduction of new radiocommunication applications within both the broadcast receivers tuning range and its coverage area require a review of these established processes.

This Report examines the differences between interference arising external to and internal to the broadcast coverage area. Further it considers the implications of assessing interference on a "global" and "local" basis, and develops a conceptual method for reporting and representing coverage loss in terms of the degradation to the location probability It needs to be noted that there are other approaches to represent the loss in the broadcasting coverage. For instance, the GE06 Agreement considered this issue in terms of the usable and nuisance field strengths.

2 Overview of the technical and operational information on broadcasting

This section provides an example of loss of DTTB coverage as a consequence of interference sources.

2.1 Concepts of coverage area loss

The goal of "broadcasting" is to distribute programmes to many listeners/viewers, usually over large areas, using one or more transmitters radiating on one or more radio frequencies. An area is said to be "covered" if reception of the programme(s) is achieved, according to specified quality criteria. Broadcast network planning is carried out in a manner to ensure that programmes can be received in predefined "coverage areas". Hence, broadcast planning is typically based on providing reception which achieves a minimum location and time reception probability/availability within a specified coverage area. Areas failing to meet this reception availability requirement are not part of the "coverage area".

Interference into broadcast services can reduce or eliminate reception in parts of the coverage area, thus resulting in broadcast "coverage area loss". Noting that broadcasters are usually required to serve well defined coverage areas for market reasons and/or in accordance with legal obligations, this can mean audience loss and consequential financial loss for the broadcaster.

2.2 Broadcast coverage

In Fig. 1, a broadcast transmitter is depicted. The transmitter has a given ERP, uniform effective antenna height (h_{eff}), and non-directional antenna with a circular coverage area. The green surface in Fig. 1 represents the coverage area; the red circle (radius "R") is the boundary edge of the coverage area.

For the sake of an example, the following text uses the 95% location probability value usually defined for coverage. However, depending on the planning requirement or broadcast standard, other suitable values, for example 90% or 99%, could also be used without changing the basic concepts. Administrations may seek to apply different percentages of location probability which suit their particular spectrum planning requirements.

FIGURE 1

Circular coverage area
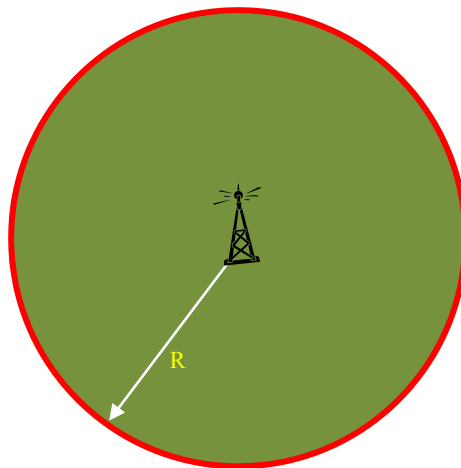
2.3   Pixel coverage

Within any part of the coverage area, a "small area"[1], sometimes called a "pixel", is defined as covered if a given percentage of the reception points inside that area is "covered". If the "given percentage[2]" (called the "location probability") is, say, 95%, this means that (at least) 95% of the reception points in the "small area" are covered, in which case, explicitly,

$E > N_{nuis}$ (noise only)

$E > E_{Inuis}$ (interference only)

$E > E_{Inuis} \oplus N_{nuis}$ (noise plus interference)

for (at least) 95% of the locations (points/sites) within the small area. It is understood that those locations which are not covered, are randomly spread across the pixel. This allows faulty reception, in marginal reception cases, to be restored, for example, in the case of interference from another broadcast transmitter, usually by relocating the receiving antenna somewhere within about 1 m of its original position.

2.4   Area coverage

The **coverage area** consists of all pixels which are covered; that is, 100% of the pixels within the coverage area, **each** have at least 95% of their reception points/sites covered.

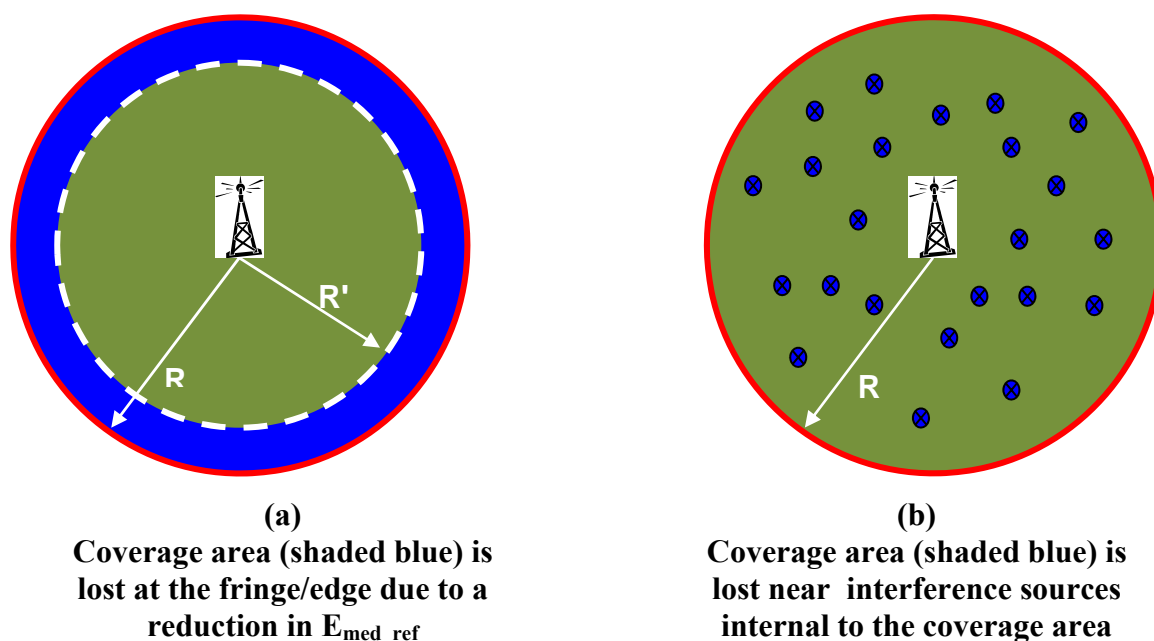[1]   A "small area" is sometimes taken to be of the order of 100 m × 100 m.

[2]   Typical values are 70%, 95% or 99%.

2.5 Reduction of coverage

If the distance at which the reference median field strength (E_{med_ref}) is reached (see Fig. 1) is reduced from R to R′, say, the area covered is also reduced, as shown in Fig. 2a, where the original coverage area, within the red solid circle, is reduced to that within the white dashed circle.

If interference sources are located across the broadcast coverage area, interference could affect areas within the original coverage area if the pixel coverage percentage is reduced below 95% (see Fig. 2b), with a consequent reduction of the total coverage area.

FIGURE 2

Reduced coverage area (green)

(a)
Coverage area (shaded blue) is lost at the fringe/edge due to a reduction in E_{med_ref}

(b)
Coverage area (shaded blue) is lost near interference sources internal to the coverage area

2.6 Coverage area loss

The blue area between the solid and dashed circles in Fig. 2a, and between the solid circle and the areas within the small circles in Fig. 2b, represent the "**coverage area loss**", which can be expressed as a percentage of the original area

% coverage area loss = 100·(coverage area lost)/(original coverage area)% or

% coverage area loss = 100·blue area/(green area + blue area)%.

2.7 Interference implications

The distinction between "local" (i.e., within a small area) and "global" (i.e., across the coverage area) interference effects and how they are assessed require careful examination. For example, a "local" interference probability of 1%, may be uniformly distributed near the broadcast coverage fringe/edge (producing coverage loss within a boundary edge "strip"), whereas the interference probability may be only 0.001%, near the broadcast transmitter, with intermediate values in between. In the example above, the "global" interference probability is averaged over the entire broadcast coverage area and may be only 0.1%. Hence, a "global" interference probability, averaged over the whole coverage area, might seem to be acceptable, but it might not identify

an unacceptably high "local" interference probability at the coverage fringe/edge and/or at isolated points within the coverage area.

Therefore as the broadcast service is generally most sensitive at the coverage fringe/edge (wanted field strength is at or near the lower limit for good reception) the acceptable interference criterion should be especially suitable at that fringe/edge (see Annex 1).

3   Reduction of coverage

A reduction in broadcast coverage is generally termed a "coverage hole", irrespective of whether it is manifested as a general loss of coverage along the boundary of a broadcast service area or as holes in coverage at points within the service area.

"Coverage holes" can be created within a covered broadcast area due to individual interference sources located inside or outside the original broadcast coverage area, they may also be created due to the aggregation of interference from multiple sources of interference located inside and/or outside the original broadcast covered area.

In the case of coverage holes created by interference from source(s) external to the broadcast coverage area, the coverage holes may be of any size and shape depending on the number of such interference sources, their precise location and whether they are operating on one or more broadcast transmission channels (N, N ± 1, N ± 2, N ± 3, etc.) relative to the wanted broadcast transmission on channel N (i.e. depending on the number and type of interference sources they may be co-channel and/or adjacent channel).

In the case of coverage holes created by interference from sources internal to the broadcast coverage area, they might be small, roughly circular areas (e.g. centred at a mobile transmitter) within which a very high interfering field strength is produced. These holes (illustrated in Fig. 2b, as small blue circles) may arise from individual interfering transmitters operating on one or more broadcast transmission channel offsets (N ± 1, N ± 2, N ± 3, etc.) relative to the wanted broadcast transmission on channel N (i.e. they are adjacent channel only).

The spatial distribution of the interfering field strength within coverage holes created by interference within the service area is fundamentally different than that of the interference caused by an externally situated source of interference, for example by a co-channel broadcast transmitter.

a)   In the case of a coverage hole created by an "external" distant interfering broadcast transmitter, the variation of the reception location probability within the area of coverage loss varies only a few per cent over distances of, say, 10s of metres.

b)   In the case of a coverage hole created by internal interference, the location probability within the area of coverage loss may vary by more than 95% over distances of 10s of metres, due to the shorter interference path.

In case a), if the location probability has not been degraded by too large an amount (e.g. about 1%), broadcast reception at individual reception sites might be restored by moving the broadcast receiver antenna a short distance, say about 0.5 to 1 metre.

In case b), broadcast reception will in general be deficient throughout the entire coverage hole – in that case there will be no possibility to move the broadcast receiver antenna short distances, say about 0.5 to 1 metre, to regain lost reception. If the interference arises randomly in time and location it may block reception for several minutes. Thus, this type of interference must be evaluated differently than normally done in a broadcast vs. broadcast interference situation.

The differences in the effects of an interference probability which is small and spread uniformly over an area (e.g. at the coverage fringe) and those of an interference probability which is small

with respect to a large area but not spread uniformly (i.e. is "lumpy") are significant for broadcast reception. Hence, non-uniform interference situations may lead to a requirement for alternative criteria for evaluation of the necessary protection limits.

Furthermore, if the interference is of a time-varying nature these additional factors must be defined, the corresponding length of time of the interference, rate of interference incidence.

Annex 1

Examples of the relationship between interference probability and coverage area loss

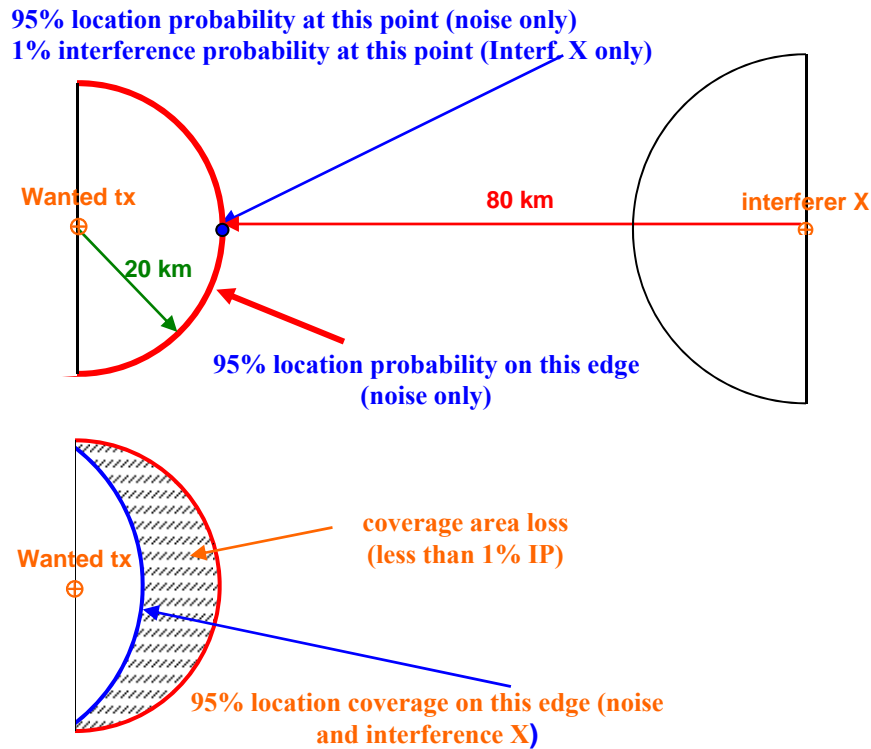## A   Schematic example with broadcast vs. broadcast interference

In order to understand the relationship between "interference probability" and "coverage loss", the following simple example is taken from broadcast planning methodology.

At the top of Fig. 3, a situation is shown where a wanted transmitter achieves a semi-circular coverage in the presence of noise only. That is, the boundary of the wanted coverage area is defined by the limit where a 95% location probability of reception is achieved in the presence of noise only[3]. A new, interfering Broadcast transmitter, "X", is introduced at the right, its ERP, distance, etc. are chosen such that an interference probability of 1% is introduced at the closest point on the wanted coverage boundary in the absence of noise[4]. As the wanted coverage edge (and interior to the coverage edge) curves away from the interferer the interference probability within the coverage edge will diminish because of decreasing interference field strength (and increasing wanted field strength).

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[3] $E_w > E_{min} \oplus N [\oplus I]$ at least at 95% of the locations on the coverage edge. ("$\oplus$" indicates a power sum.)

[4] A 1% interference probability means $E_w > E_X + PR$ at least at 99% of the locations on the coverage edge.

FIGURE 3

Interference probability and coverage loss

95% location probability at this point (noise only)
1% interference probability at this point (Interf. X only)

Wanted tx

80 km

interferer X

20 km

95% location probability on this edge
(noise only)

Wanted tx

coverage area loss
(less than 1% IP)

95% location coverage on this edge (noise
and interference X)

In the bottom half of Fig. 3 is shown (marked in blue) the new, reduced coverage edge in the presence of the additional interference, that is, the edge where a location probability of 95% is re-established in the presence of the additional interference.

In the shaded area in between the original, red coverage edge and the new, blue coverage edge, the interference probability is less than 1%, and the location probability is less than 95%; this area which is no longer covered is a coverage area loss.

The shaded area can represent a large percentage of the original coverage area, and may be more than the 1% interference probability existing in that area. Thus, the area of coverage loss may be much more than the percentage of interference probability introduced by a new interferer.

B   Schematic example with interference into the broadcast fringe area

In this example, the interference probability is assumed to be 1%, uniformly spread over the broadcast coverage fringe area.

Before the interference source is "turned on", the coverage area is as shown in Fig. 4a. The coverage radius is r_o, where the location probability $LP_N(r_o) = 95\%$. At a smaller radius, r_i, $LP_N(r_i) = 96\%$.
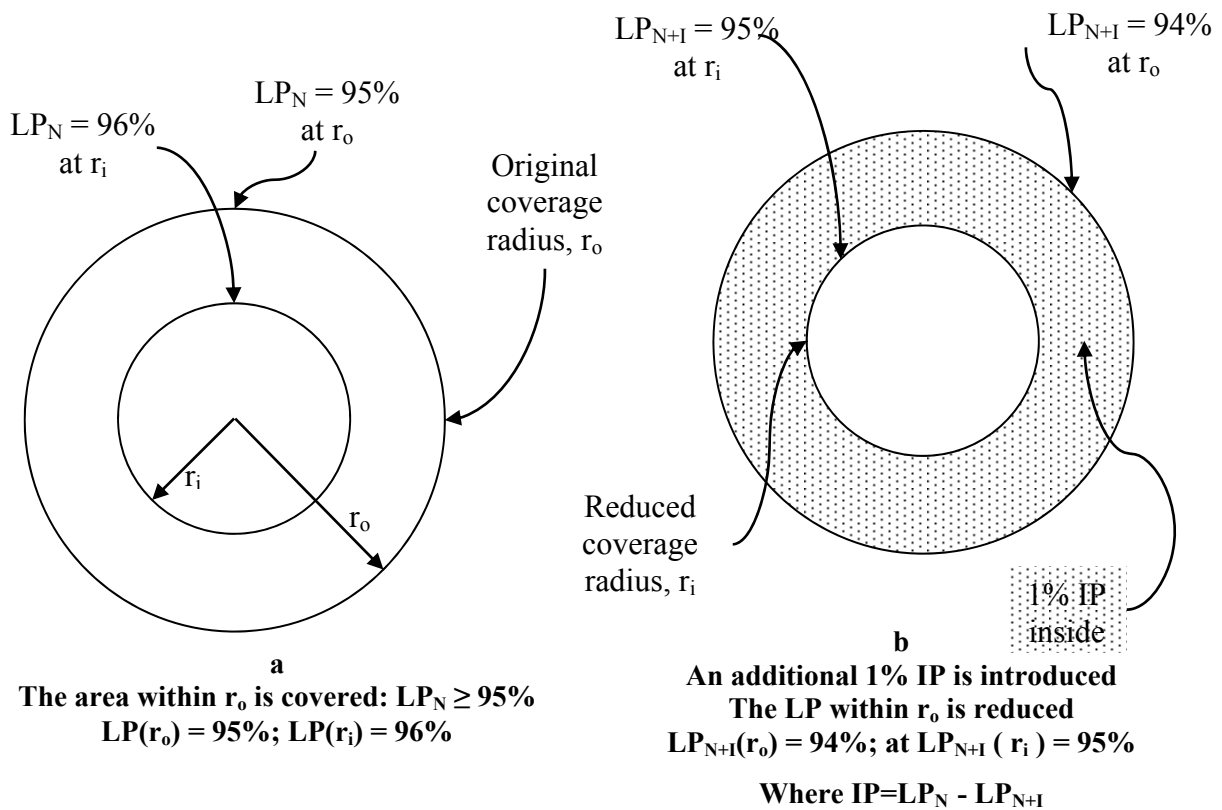
In Fig. 4b, a 1% interference probability exists due to the introduction of interference within the fringe area. Hence, the reception location probability will be reduced throughout the fringe by approximately 1%. Then $LP_{N+I}(r_o) = 94\%$ and $LP_{N+I}(r_i) = 95\%$. A new, reduced coverage radius, r_i, results.

The area in the ring between r_0 and r_1 is no longer covered because the location probability in that area is less than 95%; this area (shaded in Fig. 4b) represents the coverage area loss. This loss is larger, the smaller the reduced radius, r_i. The loss can be expressed as a percentage of the original coverage area:

$$\% \text{ coverage area loss} = 100 \{r_o^2 - r_i^2\}/r_o^2.$$

It can be seen that the % coverage area loss depends on r_o and r_i, which are not directly related to the value of the interference probability: these two values (interference probability and % coverage area loss) are not necessarily the same, and can be significantly different. Precise compatibility calculations must be carried out to determine what the numerical relationship is.

FIGURE 4

**Interference within BC coverage area: 1% IP coverage area loss (shaded)
in the fringe area**

**a
The area within r_o is covered: $LP_N \geq 95\%$
$LP(r_o) = 95\%$; $LP(r_i) = 96\%$**

**b
An additional 1% IP is introduced
The LP within r_o is reduced
$LP_{N+I}(r_o) = 94\%$; at $LP_{N+I}(r_i) = 95\%$**

Where $IP = LP_N - LP_{N+I}$

C **Schematic example with mobile interference sources inside the broadcast coverage area**

In the interior of a broadcast coverage area, the wanted field strength is stronger, the nearer the wanted transmitter: the probability that a given interference will disrupt a program becomes smaller. A smaller probability, however, must not necessarily be understood to be more acceptable for broadcast reception.

Because of the relatively high field-strength values near a mobile interfering transmitter within the coverage area, interference in concentrated "lumps" will still occur. This is to be contrasted with the interference effects due to an interference source located outside of the wanted coverage area, where the interference effects produced within the wanted coverage area are not as concentrated and occur randomly over wider areas. However, both situations will give rise to what are called coverage holes within the broadcast coverage area: coverage area will also be lost.

The coverage holes produced by interference internal to the coverage area, will tend to be smaller, the closer they are to the broadcast transmitter, see Fig. 5 for a schematic representation. The number of holes depends on the number of active mobile interference sources within the area. The holes may be relatively small, of the order of metres to 10s of metres radius, but reception will be prevented essentially everywhere within them. Moving the receiver antenna a half metre or so to re-establish lost reception, as is normally the case when the interference source is another broadcast transmitter, is not generally sufficient inside of a coverage hole.

The fact that a "small" coverage hole within a larger area represents a small interference probability does not in any way alleviate the concentrated loss of coverage within the coverage hole.

Coverage holes caused by interference from a mobile transmitter are distributed more or less randomly in space and time. Because of the randomness of the occurrence of the holes, the interference probability is not the significant factor to be controlled, rather the area of the coverage holes is more important, e.g. holes larger than 1-3 metre radius may be determined to be unacceptable for any probability of occurrence.

FIGURE 5

Coverage holes in BC coverage area
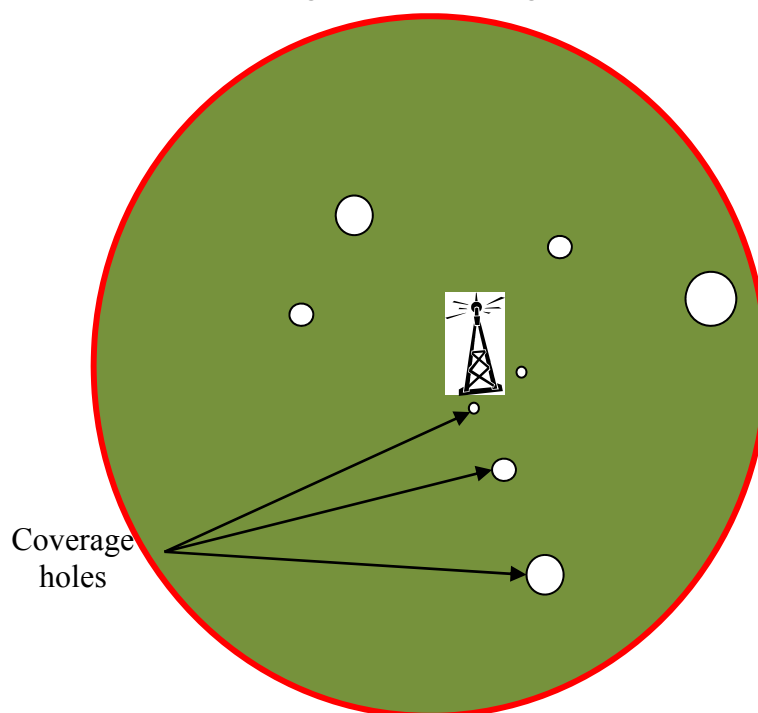
Coverage holes

D   Schematic examples with an interfering land station[5] inside the broadcast coverage area

A DTTB coverage hole is depicted in Figure 6 below.

For the purpose of the example[6] a land station is assumed to be at the centre of the circle, and located within a coverage area (the shaded rectangle in the Figure). The inner red circle represents the 95% "interference contour". It is on this contour that the location probability for good reception reaches 95% in the presence of the interfering land station only. The outer circle represents the 99% "interference contour" (in the presence of the interfering land station only).

The 99% contour is further away from the land station than the 95% contour, because the probability of good broadcast reception increases as the distance to the land station (LS) is increased. If it is assumed that there is a 95% location probability of broadcast reception in the rectangular area in the absence of the interference source, then the addition interference source will reduce the overall location probability as shown in diagram 7.

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[5]   Refer to Article 1.69 of the Radio Regulations.

[6]   This example could be applied to a transmitter in any service operating from a fixed location with appropriate adjustment for antenna radiation pattern.

For example, within the shaded region between the inner and outer circles, the overall location probability will be less than the original 95% and will range from about 90% (at the inner circle) to 94% as the outer circle is approached[7]. Outside the outer circle, the overall location probability will range from about 94% at the outer circle to (eventually) 95% farther away.

FIGURE 6
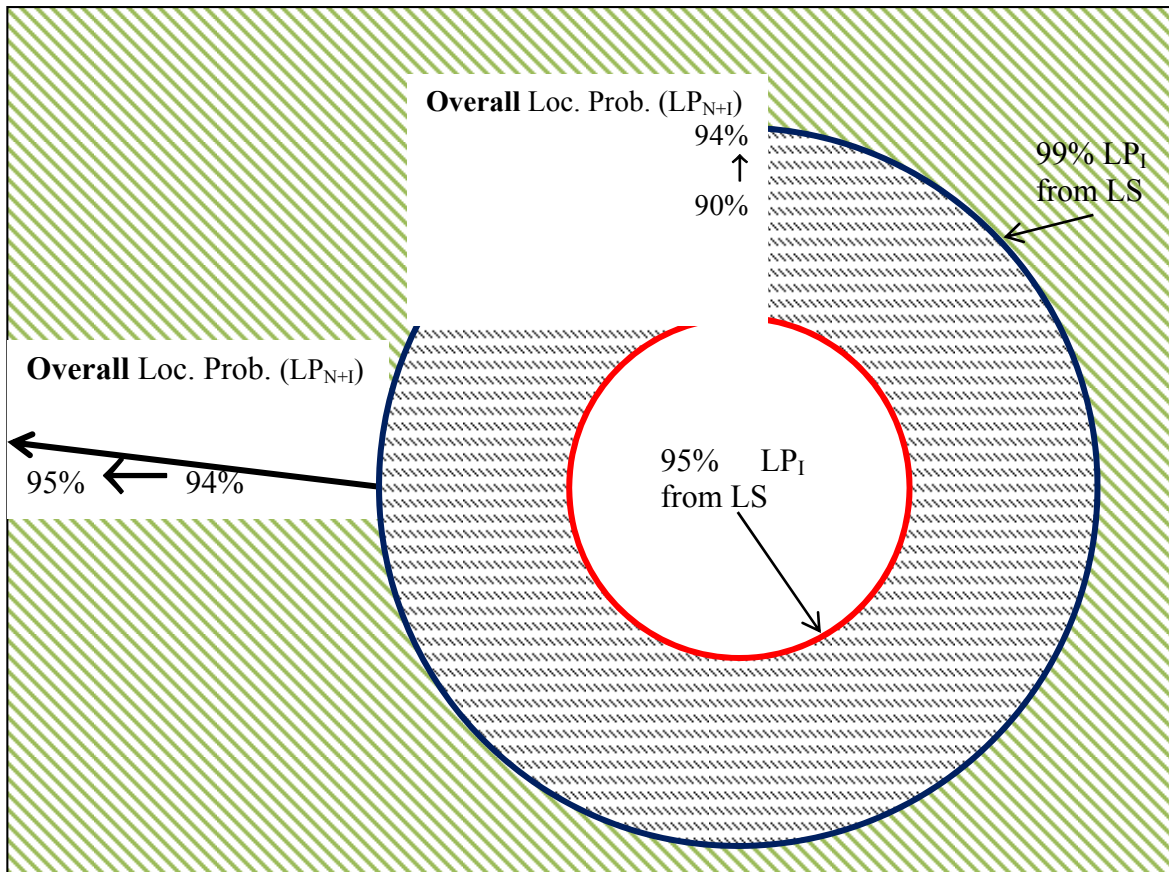
More detailed explanations are given in Figs 7 to 8 below.

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[7] Assuming independent probabilities, the overall location probability will drop to $0.95 \bullet 0.95 = 0.9025 \equiv 90\%$ and $0.95 \bullet 0.99 = 0.9405 \equiv 94\%$, at the two circles, respectively.

FIGURE 7

An interfering land station (LS) is introduced into a wanted broadcast (BC) coverage area.

The LS is at the centre of the concentric circles.

The **green horizontal axis** gives the distance, **r**, from the LS transmitter.

The **red curve and red vertical axis** (left) give the interfering LS field strength, FS_I.

The **blue curve and blue vertical axis** (right) give the location probability LP_I for acceptable reception in the presence of the interference.

Note that the LP is calculated only for the LS interference (i.e., the noise is ignored).

The **interfering field, FS_I**, decreases as the **distance, r**, increases.

As the interfering **FS_I** decreases, the **location probability, LP**, for acceptable reception of a wanted signal increases.

For example:

At **r_1**, the interfering field strength **FS_1** gives rise to a wanted **$LP_I = 15\%$**

At **r_2**, the interfering field strength **FS_2** gives rise to a wanted **$LP_I = 62\%$**

In the small circle (radius r_1) the LP_I is very small; outside the LP_I is larger.

Beyond r_2 the LP_I increases, gradually approaching 100% at very large r.
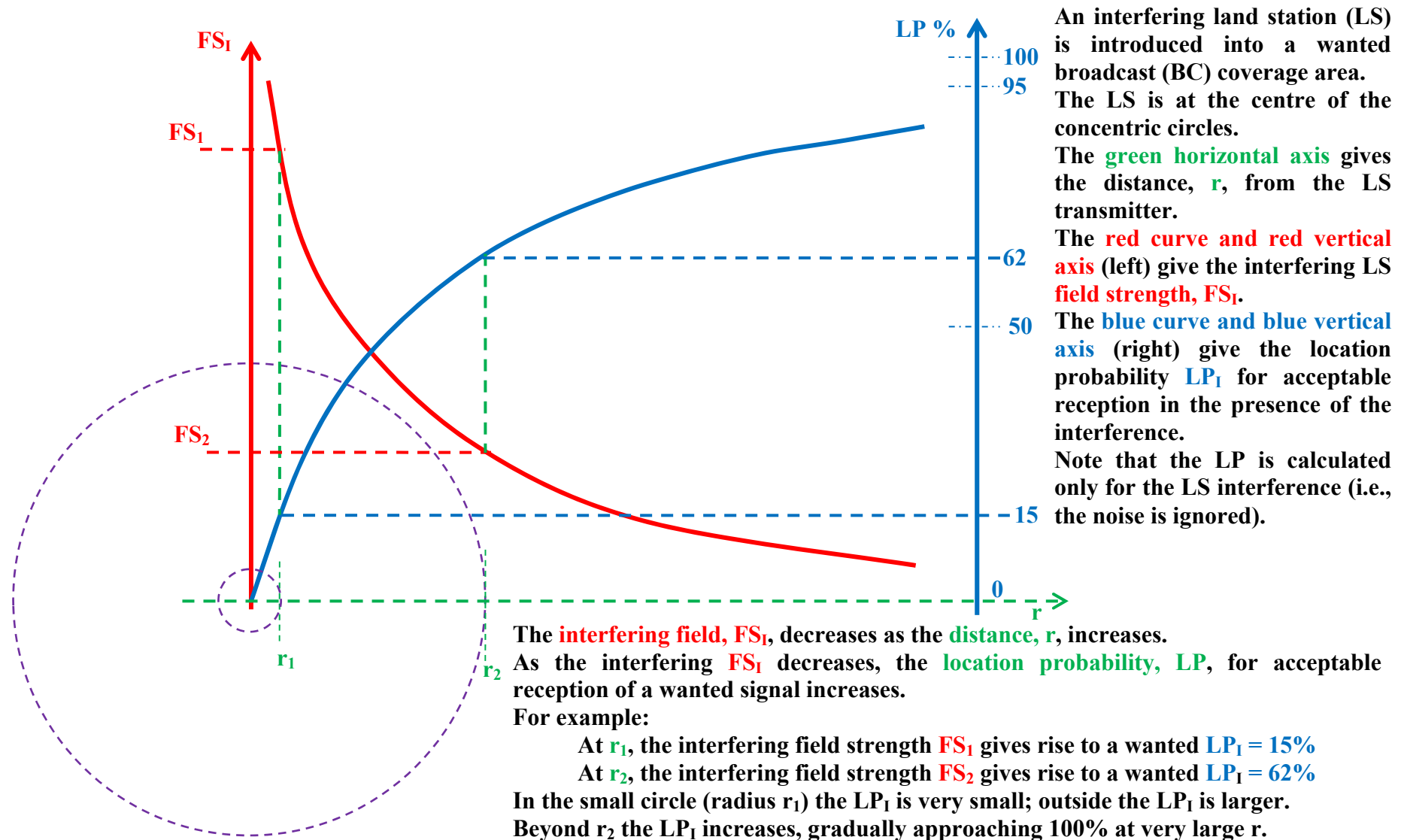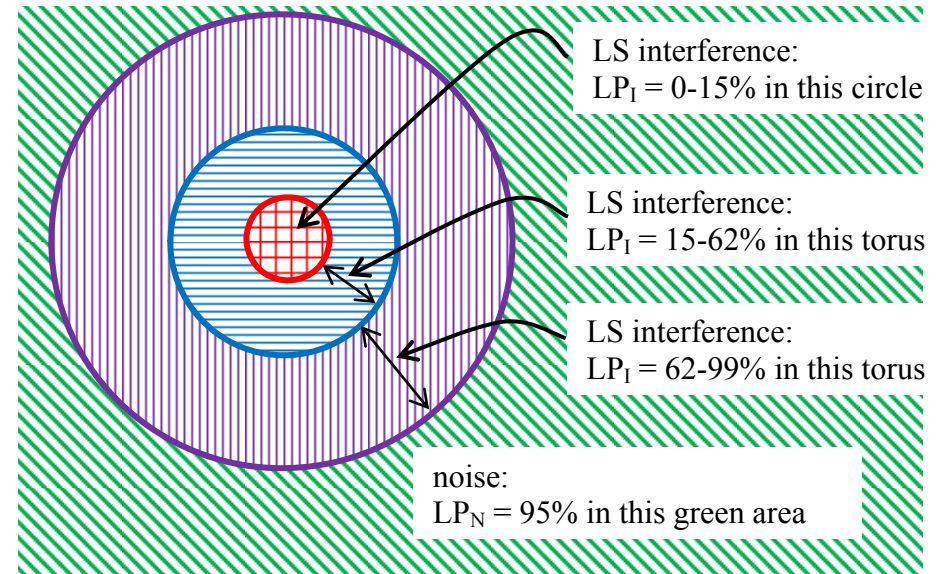
FIGURE 8a

BC area (shaded green) where an assumed uniform 95% location probability is achieved (in the presence of noise) for BC reception, before a new land station (LS) and its additional interference are introduced.

99% LP_I from LS
Individual LPs are displayed.
- the green shaded area has $LP_N = 95\%$, due to noise only,
- the circular/torus and rectangular shaped areas have LPs ranging from 0-15%, 15-62%, 62-99%, >99%, respectively, due to new LS interference only.

A new LS is introduced within the BC coverage area. Considering ONLY the LS interference (i.e. ignoring the noise):
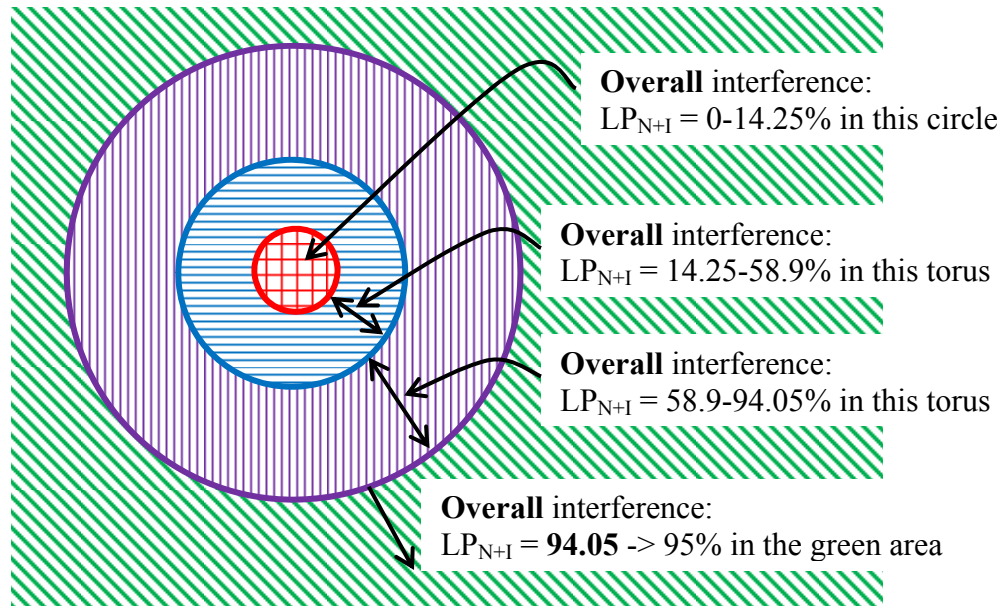- The LP_I at the red circle, radius r_1, is 15%. Inside the red circle, the LP_I is less than 15%, becoming 0 at the centre.
- The LP_I at the blue circle, radius r_2, is 62%. Between the red circle and the blue circle, the LP_I is between 15%, and 62%.
- The LP_I at the purple circle, radius r_3, is 99%. Between the blue circle and the purple circle, the LP_I is between 62%, and 99%.
- Outside the purple circle, the LP_I increases from 99% and approaches 100% as the distance from the LS transmitter increases.

FIGURE 8b

Overall interference:
$LP_{N+I} = 0\text{-}14.25\%$ in this circle

Overall interference:
$LP_{N+I} = 14.25\text{-}58.9\%$ in this torus

Overall interference:
$LP_{N+I} = 58.9\text{-}94.05\%$ in this torus

Overall interference:
$LP_{N+I} = \mathbf{94.05} \rightarrow 95\%$ in the green area

A new LS is introduced within the BC coverage area.
Considering the **overall** interference (i.e. combining the noise with the new, additional LS interference):
- The LP_{N+I} at the red circle, radius r_1, is 14.25%. Inside the red circle, the LP_{N+I} is less than 14.25%, becoming 0 at the centre.
- The LP_{N+I} at the blue circle, radius r_2, is 58.9%. Between the red circle and the blue circle, the LP_{N+I} is between 14.25%, and 58.9%.
- The LP_{N+I} at the purple circle, radius r_3, is 94.05%. Between the blue circle and the purple circle, the LP_{N+I} is between 58.9%, and 94.05%.
- Outside the purple circle, the LP_{N+I} increases from 94.05% and approaches 95% as the distance from the LS transmitter increases.

Combined probabilities
$LP_{N+I} = 99\%$ protection from LS

If a simple combination of the probabilities is undertaken, the circular/torus and rectangular shaped areas have LPs ranging

from 0 to 14.25%,
from 14.25 to 58.9%,
from 58.9 to 94.05%,
greater than **94.05%**,

respectively, due to noise plus new LS interference.