RECOMMENDATION ITU-R SA.1281*

PROTECTION OF STATIONS IN THE RADIOLOCATION SERVICE FROM EMISSIONS FROM ACTIVE SPACEBORNE SENSORS IN THE BAND 13.4-13.75 GHz

(Questions ITU-R 213/7 and ITU-R 204/8)

(1997)

The ITU Radiocommunication Assembly,

considering

a) that Resolution 712 (Rev.WRC-95) of the World Radiocommunication Conference (Geneva, 1995) calls for studies of the compatibility of the use of existing allocations for space-based active sensors operating in the Earth exploration-satellite and space research services in frequency bands shared with the radiolocation or radionavigation services, between 1 and 25 GHz, with a view to the possibility of establishing common worldwide primary allocations;

b) that the band 13.4-14.0 GHz is allocated to the radiolocation service on a primary basis, with additional allocations to the radionavigation service in several countries on a primary basis;

c) that currently the band 13.4-14.0 GHz is allocated for spaceborne radiolocation stations (active spaceborne sensors) on a secondary basis;

d) that these studies have shown that existing and planned terrestrial radars and active spaceborne sensors in the 13.4-13.75 GHz band are operationally compatible;

e) that to insure future operational compatibility, restrictions need to be placed on spaceborne active sensor emissions;

f) that performance degradations that spaceborne sensors could cause to terrestrial radars are of two major types:

– desensitization of detection and tracking of valid targets;

– the introduction of false-target effects;

g) that terrestrial-radar desensitization is acceptable if its frequency of occurrence is sufficiently low and does not compromise the radars' mission requirements;

h) that analyses have shown that desensitization induced by representative spaceborne sensors is acceptably infrequent;

j) that constraints on spaceborne-sensor designs are not required to prevent unacceptable desensitization;

k) that the nature of radar missions in this band makes certain false-target responses unacceptable even if they were to occur quite rarely;

l) that tests have resulted in interference exposure limits that protect the radar systems against unacceptable false-target responses;

m) that avoidance of unacceptable false-target responses requires that these exposure limits be imposed without regard to their frequency of occurrence;

n) that expression of these limits in terms of W/(m^2 · MHz) could expose wideband radar receiver front ends to excessive interference powers, while expression in terms of W/m^2 without regard to emission bandwidth can provide the needed protection,

* This Recommendation was jointly developed by Radiocommunication Study Groups 7 and 8, and future revisions should be undertaken jointly.

recommends

1 that the power density produced at any given point on the Earth's surface by emissions from spaceborne active sensors operating in the Earth exploration-satellite and space research services in the band 13.4-13.75 GHz for all methods of modulation should not exceed:

-71	$dB(W/m^2)$	for $0° \leq \delta \leq 6°$
$-71 + (\delta - 6°)/3$	$dB(W/m^2)$	for $6° < \delta \leq 15°$
-68	$dB(W/m^2)$	for $15° < \delta \leq 70°$
$-68 + 1.1(\delta - 70°)$	$dB(W/m^2)$	for $70° < \delta \leq 90°$

where δ is the angle of arrival of the radio-frequency wave (in degrees above the horizontal plane) and these limits relate to those which would be obtained under assumed free-space propagation conditions during the worst-case pass of a sensor satellite;

2 that the values in *recommends* 1 may be exceeded by up to 24 dB if either:

2.1 the values are exceeded in excursions of less than 0.1 s duration consisting of either continuous emissions or envelopes connecting the peaks of trains of successive pulses, and each of those excursions is separated from the next by at least 0.4 s; or

2.2 during a complete satellite pass, the sum of all the continuous-emission or pulse-train-envelope excursions above the values in *recommends* 1 is less than 0.1 s and the total span of time between the first and last crossings of those values is less than 0.4 s;

3 that the method given in Annex 1 may be used to determine whether a given sensor complies with *recommends* 1 and 2, and that Figs. 1 to 4 may be used as graphic illustrations of the criteria themselves.

ANNEX 1

Procedure for determining compliance with *recommends* 1 and 2

1 Procedure

In this Annex, "long dwell" applies to the case addressed by *recommends* 1 and "short dwell" applies to the cases addressed by *recommends* 2, while "dwell time" and "look-away time" are defined explicitly in item 5b of this section and are illustrated in Figs. 2, 3, and 4. For any given spaceborne sensor, the practical application of these *recommends* can be broken down into the following step-by-step decision-tree procedure:

Step 1: Determine the sensor's profile of worst-case peak power density vs. elevation angle of arrival at the Earth. This is done by using the sensor's satellite altitude, transmit peak power, antenna gain pattern, and main-beam pointing angles to compute power densities for the worst-case scan mode and time within the scan for a representative set of cross-track distances corresponding to elevation angles from 0° to 90°.

Step 2: Plot or overlay that power-density-vs.-elevation-angle profile on the compatibility limit for "long-dwell" exposure (from *recommends* 1) and the 24 dB-higher limit for "short-dwell" exposure shown in Fig. 1.

Step 3: If the sensor's power-density profile lies entirely below the "long-dwell" compatibility profile, compatibility is indicated and no further analysis is needed.

Step 4: If the sensor's power-density profile exceeds the maximum limit for "short-dwell" exposure at any elevation angle, the compatibility criteria are not met; no further examination is needed.

Step 5: If the sensor's power-density profile exceeds the "long-dwell" exposure (*recommends* 1) compatibility limit at any elevation angle but does not exceed the limit for "short-dwell" exposure, it will be necessary to determine whether the power-density excursions above the "long-dwell" limit satisfy the "short-dwell" criteria of *recommends* 2.1 or 2.2. If scanning is to be implemented by means of beam switching, this can be done simply by comparing the beam-switching times with the critical dwell and look-away times.

Substep 5a: If scanning is not implemented so simply, computations will be needed to determine whether the exposure satisfies the "short-dwell" criteria; i.e. *recommends* 2.1 or 2.2. The first substep required to accomplish that is to determine the fine-grain pattern of power density envelope vs. time that the sensor would impinge on a fixed terrestrial point under worst-case conditions. This envelope pattern is again determined by the sensor's altitude, antenna-beam gain and scanning characteristics, and peak transmitter power, not by any pulsing of the transmitter. The worst-case conditions include the cross-track distance and corresponding elevation angle of arrival at the earth for which the power-density profile most exceeds the "long-dwell" exposure-limit (*recommends* 1) profile. (This usually occurs at or close to the sensor's maximum-power-density elevation angle.) This can be done via computations similar to those that are normally necessary in the design of active spaceborne sensors. They would produce a pattern more or less similar to the ones in Figs. 2, 3, or 4.

Substep 5b: Compare the fine-grain temporal pattern of power density envelope with the "long-dwell" (*recommends* 1) compatibility limit for the associated elevation angle. This can be done simply by passing a constant-power-density line through the temporal pattern at the "long-dwell" compatibility level corresponding to the worst-case elevation angle determined from the plot constructed in step 2. From the crossings of that line, observe the durations of the power-density lobes' or envelopes' excursions above it and the associated times separating successive excursions. These are referred to as "dwell times" and "look-away times", respectively.

If any individual dwell times exceed 0.1 s, the exposure is of the "long-dwell" type and the compatibility criteria are not met. No further examination is needed.

If all the individual dwell times are less than 0.1 s and the look-away times all exceed 0.4 s, compatibility is indicated by *recommends* 2.1 and no further examination is needed.

If the individual dwell times are all less than 0.1 s but some or all look-away times do not exceed 0.4 s, determine the sum of all dwell times during a satellite pass; i.e. the cumulative time for which the power density of continuous emissions and/or pulse-train envelopes exceeds the "long-dwell" power-density limit profile. (This addresses *recommends* 2.2.)

If that sum of all dwell times in a satellite pass exceeds 0.1 s, the compatibility criteria are not met. No further examination is needed.

If that sum of all dwell times in a satellite pass is less than 0.1 s, determine the total span of time between the first and last crossings of the "long-dwell" power-density-limit profile. If that span is less than 0.4 s, compatibility is indicated by *recommends* 2.2 and no further examination is needed. But if that span exceeds 0.4 s, the compatibility criteria are not met. No further examination is needed.

2 Examples

The procedure described above can be implemented straightforwardly even when step 5 (including substeps 5a and 5b is required; i.e., even when *recommends* 2 applies. That is illustrated by the three following examples, all of which deal with *recommends* 2. Figure 1 applies to all three examples in that the *recommends* 1 limit profile is exceeded most at elevation angles for which that limit has the value –68 dB(W/m^2); Figs. 2, 3, and 4 apply to the first, second, and third, examples, respectively.

The first example illustrates *recommends* 2.1. For the cross-track distance corresponding to the worst-case elevation angle, one performs substep 5a by generating the power density-vs.-time pattern for the envelope of power density. For this example, that pattern is as shown in Fig. 2. To begin substep 5b, the compatibility limit for "long-dwell" exposure for that elevation angle is noted from *recommends* 1 or Fig. 1. One then simply draws a horizontal line across the power-density-vs.-time plot at that power density limit, as shown in Fig. 2. (Because step 4 has already been completed, the "short-dwell" limit need not be drawn, although it is shown in Fig. 2 for completeness.) The next operation is to measure the dwell and look-away times. If the time axis of the plot uses a suitable scale, that can be done from the plot itself simply by measuring the times between the points where the power-density-envelope lobes cross the "long-dwell" compatibility limit. (A pair of dividers might be helpful.) Note that the dwell time is measured on the pulse-train envelope, not on individual pulses.) Whether the "dwell time" and "look-away time" criteria are met can thus be readily determined. In the example shown in Fig. 2, the dwell time is less than 0.1 s and the look-away time exceeds 0.4 s, so *recommends* 2.1 applies and the hypothetical sensor is compatible.

FIGURE 1

Power density limits of hypothetical profile of worst-case sensor power density vs. elevation angle

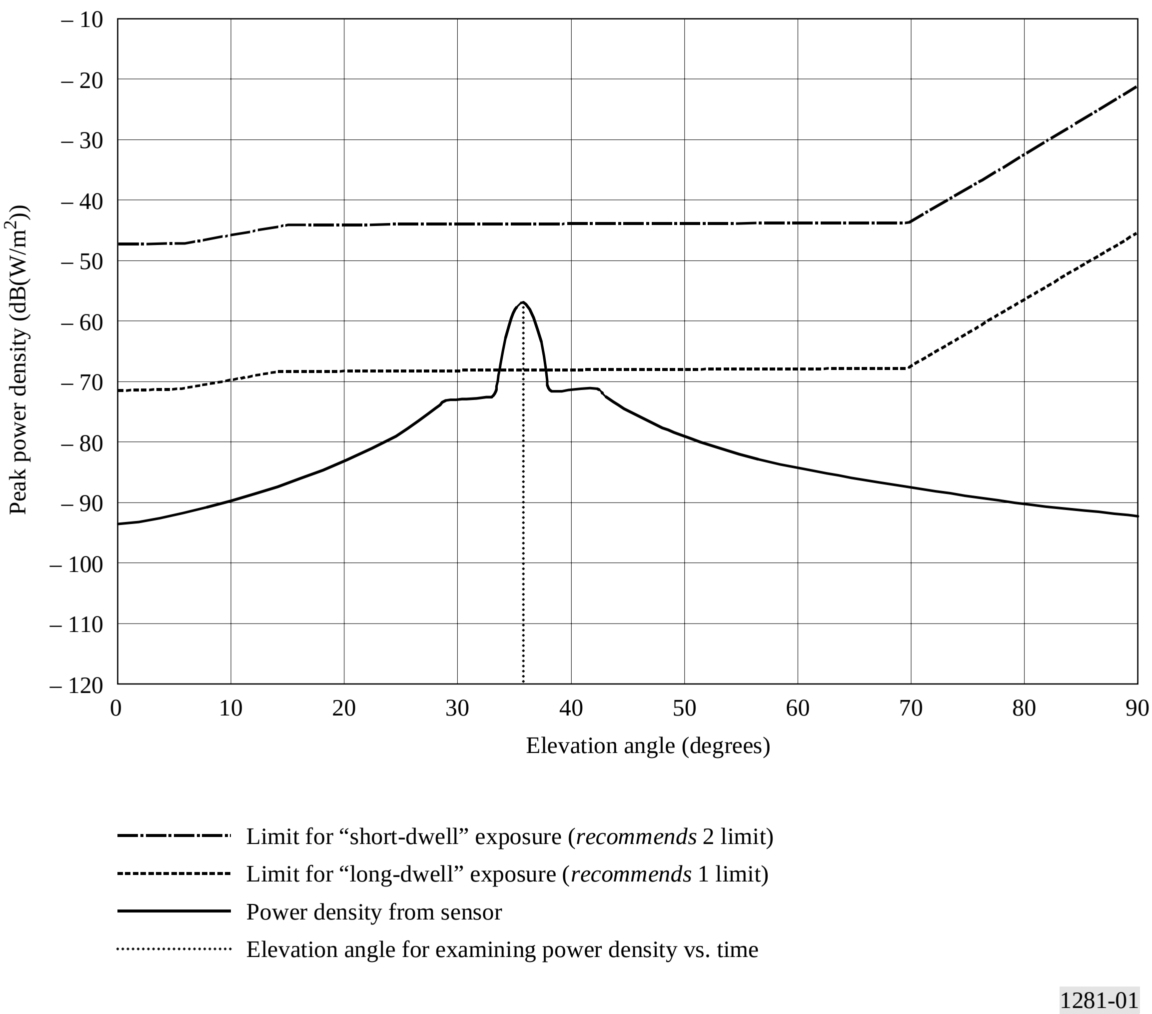
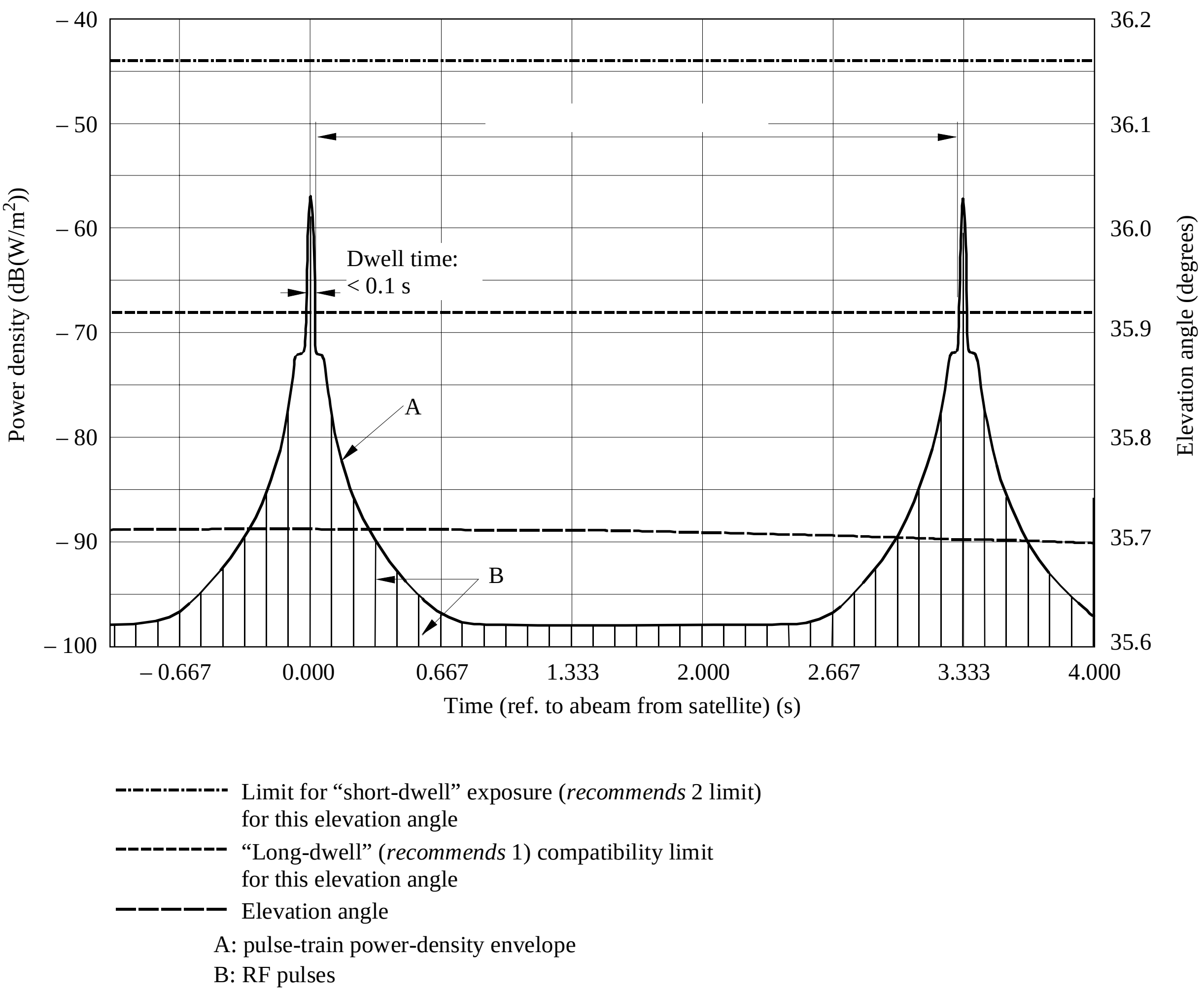


FIGURE 2

Hypothetical power density vs. time pattern illustrating application of *recommends* 2.1. Sensor fails *recommends* 1 but is compatible by virtue of *recommends* 2.1.



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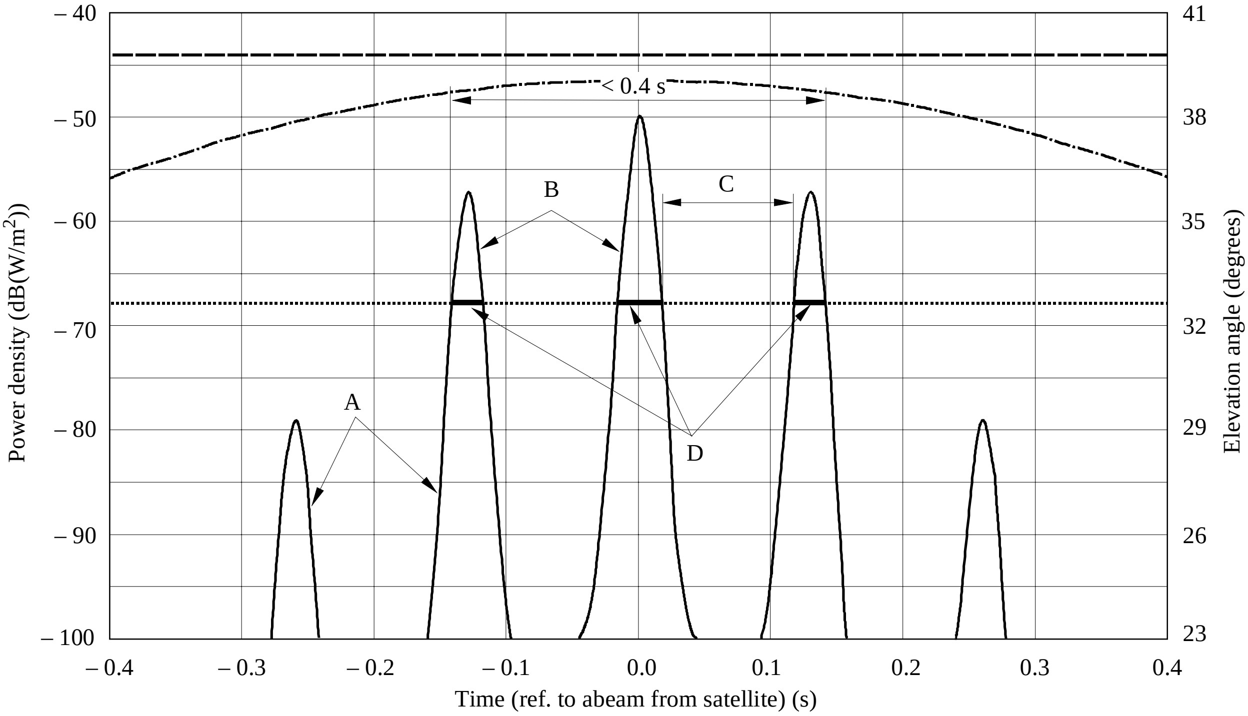
The second example illustrates *recommends* 2.2. First the profile of peak power density vs. elevation angle is generated (step 1). The overlay of that peak-power-density-vs.-elevation-angle profile and the *recommends* 1 and *recommends* 2 limits profiles (step 2) is again postulated to be similar to Fig. 1, from which it will be clear that step 5 must be performed. The critical elevation angle and associated worst-case cross-track distance are then determined. In this case, suppose the critical elevation angle is 38.8° and the associated peak power density is –50 dB(W/m^2). Then the power-density-vs.-time pattern is generated for the corresponding cross-track distance (substep 5a). Suppose that pattern is as shown in Fig. 3. Note that the lobes in that Figure represent the envelope of the waveform; it is irrelevant whether the waveform under that envelope is pulsed or continuous-wave. A horizontal line is drawn across that pattern at the pertinent long-dwell (*recommends* 1) limit, and the "dwell time" and "look-away time" are determined by the widths of and separations between the lobes at that power-density level (substep 5b). In Fig. 3, the "dwell times" are indicated by short, thick horizontal lines. Substep 5b is concerned solely with their lengths and the lengths of time separating them. In this case, the "look-away" times are less than 0.4 s, so *recommends* 2.1 does not apply. However, the individual "dwell times" are less than 0.1 s, so it is necessary to determine whether *recommends* 2.2 applies. That is done by evaluating the "dwell times" quantitatively and summing them. In this example, the sum is slightly less than 0.1 s and the first and last crossings of the *recommends* 1 limit are separated by less than 0.4 s. Therefore, the sensor is compatible.

FIGURE 3

Hypothetical power density vs. time pattern illustrating application of criteria to continuous emission sensor that fails *recommends* 1 and 2.1 but passes *recommends* 2.2



Recommends 2 limit

Elevation angle

Recommends 1 limit

A: continuous emission power density

B: fails *recommends* 1

C: look-away time < 0.4 s (fails 2.1)

D: sensor is compatible by *recommends* 2.2 because: sum of these dwell times < 0,1 s and the first and last crossings are separated by < 0.4 s

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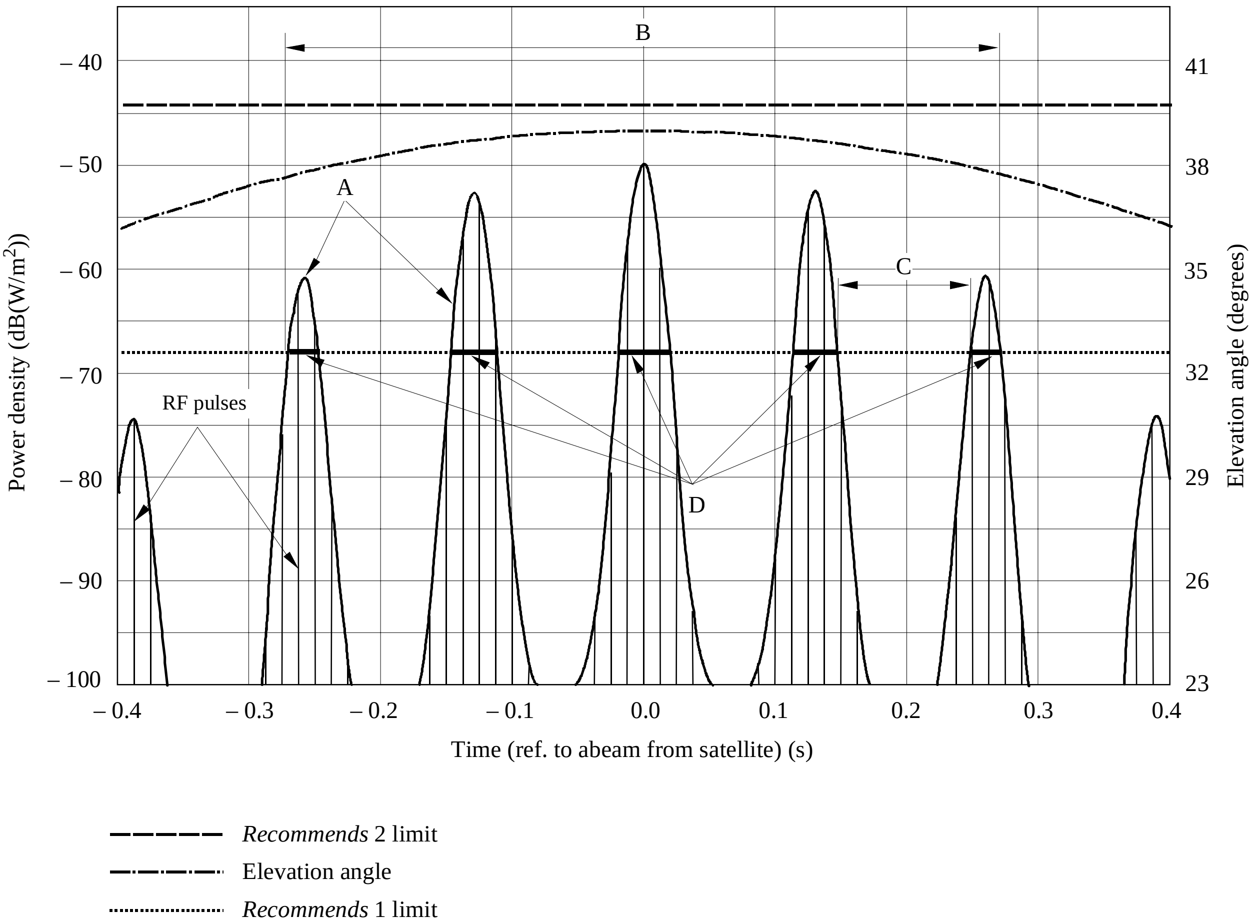
A third example also illustrates *recommends* 2.2. Steps 1 through 4 proceed exactly as they did in the second example and step 5 is again needed. In this example, substep 5a) produces the power-density envelope shown in Fig. 4. In this example, the waveform itself is shown as a sequence of RF pulses inside the envelope. However, the details of the waveform under the envelope are irrelevant to the compatibility criteria. Although the percentage of RF on time is low, the “dwell times”, as well as the “look-away times”, are again determined from the widths of the envelope lobes at the pertinent *recommends* 1 limit and the times separating them, respectively, and substep 5b is based solely on those envelope-determined times. Each “dwell time” by itself is less than 0.1 s, but the “look-away times” are less than 0.4 s, so *recommends* 2.2 applies. In this example, however, the sum of the “dwell times” is about 0.16 s, so the sensor is not compatible. The sensor also fails to meet the *recommends* 2.2 requirement that the first and last crossings of the *recommends* 1 limit be separated by less than 0.4 s.

FIGURE 4

Hypothetical power density vs. time pattern illustrating application of criteria to pulsed sensor that fails *recommends* 1 and 2 (2.1 and 2.2)



A: envelope of pulsed power density (fails *recommends* 1)

B: > 0.4 s (fails *recommends* 2.2)

C: look-away time < 0.4 s (fails *recommends* 2.1)

D: sensor also fails *recommends* 2.2 because sum of these dwell times > 0.1 s

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