Determining Necessary Adjacent Channel Isolation and Re-use Distance for a Radiocommunication Service

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SUMMARY A model for a radiocommunication system is used to estimate the service reliability when various levels of interference from co-channel and adjacent channel services are considered. A reasonable objective in spectrum planning is to choose an adjacent channel isolation and a co-channel frequency re-use distance such that both interference mechanisms degrade service reliability by about the same order. The results are used as a basis for selecting both the transmitter emission limit and a re-use distance for a new point-to-multipoint service.

1 INTRODUCTION

When a radiocommunication service is planned, the frequency band allocated to the service is usually divided into channels of equal bandwidth. The emission limit for each transmitter using a channel is then usually chosen such that only a small amount of the emission from one channel falls into adjacent channels. This out-of-band emission reduces the isolation between services using adjacent channels and depending on operational requirements may reduce the reliability of the service. Service reliability is measured in terms of the probability of achieving a given wanted to unwanted signal level ratio (or protection ratio) at an arbitrary location within a defined service area. The unwanted signal is usually a sum of interference powers from different sources, e.g., adjacent or co-channel services.

Of course the ability of the receiver operating in the adjacent channel to discriminate against the out-of-band emission also affects the degree of interference. This discrimination by the receiver is called adjacent channel selectivity. Adjacent channel selectivity is mainly dependent upon the characteristics of the IF filter of the receiver and may be measured by a number of well-known methods [1]. These methods seek to model an interference situation. However one of the main objectives of these measurement methods is repeatability and hence the model test is simplified. As a result, the value for adjacent channel selectivity is not representative of the actual isolation experienced between two adjacent services in normal operation. In the discussion which follows the term "adjacent channel isolation" is used to refer to the average isolation between two adjacent channels in normal operation. Adjacent channel isolation is affected by both receiver selectivity and the emission of the adjacent transmitter. Adjacent channel isolation is the difference in dB between the total power of a modulated transmission on its assigned frequency and the power of out-of-band and spurious emissions within the necessary bandwidth of a receiver on the adjacent channel. The modulated transmission is such that its power spectral density curve is a time average of transmissions for the service. Adjacent channel isolation may be measured using the procedure described in reference 2. Note that the "R" values mentioned in this reference do not include the

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protection ratio required to achieve a grade of service of 12 dB SINAD. If the absolute values of R have 5 dB added to them the value for adjacent channel isolation is obtained. A protection ratio of 5 dB results in a grade of service of about 12 dB SINAD for these systems.

In addition, co-channel interference resulting from another station using the same frequency but separated from the wanted channel by a large distance (usually called the re-use distance) may also reduce the service reliability. A reasonable objective is to choose both an adjacent channel isolation and a co-channel frequency re-use distance such that they both degrade service reliability by about the same order. For example there is no practical gain in applying a re-use distance which results in a 0.1% reduction in service reliability when the adjacent channel isolation causes a 10% reduction in that reliability.

Use of the radio frequency spectrum has now reached a stage where more and more services are being crowded into limited spectrum space. Obviously there is a trade-off between channel width, emission limit, selectivity and re-use distance. Therefore spectrum planners need a method of selecting both a worst case adjacent channel isolation together with a minimum re-use distance such that the overall service reliability remains acceptable.

The following analysis relates to a two-frequency mode of operation, i.e., a central station transmits on one frequency to outlying stations which transmit on another frequency.

2 SYSTEM MODEL

The median propagation loss model at 500 MHz (i.e., 50% locations, 50% time) is based on references 3 and 4 with the central stations co-located at a prime site (about 200 m in height) in an urban area and the outlying stations at 10 m. The antennas used in all cases are omnidirectional.

This model is applicable to other operating frequencies (i.e., UHF band) and antenna heights, for example, mobiles at 1.5 m, because only relative signal strengths are considered throughout the following analysis. When variation in the median field strength is caused by topography (shadowing) both the wanted and unwanted signal levels are assumed to be log-normally distributed with a variance of 6 dB and with zero correlation between the wanted and unwanted signals. The unwanted signal is normally caused by two services adjacent to the wanted. When there is additional variation in field strength due to multi-path propagation (fading in a mobile service) the distribution of field strengths is combined Rayleigh and log-normal. Then for a given separation in median wanted to unwanted signal levels, the probability of achieving a defined protection ratio (a minimum wanted to unwanted signal level ratio) may be read from the nomograms given in reference 5.

Other assumptions relate to the distribution of the outlying stations and transmission probability. The outlying stations are assumed to be located at a constant density throughout a circular service area. Then the probability of finding outlying stations at any distance from the central station may be represented by a triangular distribution function.

If (x) is the distance from the centre of a circular service area then the probability density function is :

$$f(x) = \frac{2 * x}{(\text{service area radius})^2}$$

Concerning transmission probability, whenever a central station transmits, it may or may not cause adjacent channel interference depending on whether the adjacent remotes are receiving. The central station is assumed to be transmitting continuously. This assumption is based on a polling system for a data service or a trunked system for a mobile service. Similarly a co-channel signal will have the same transmission probability and thus may be simply taken into account in the analysis.

3 ADJACENT CHANNEL INTERFERENCE

For adjacent channel interference the variables are:

adjacent channel isolation,

minimum protection ratio,

service area radius,

fixed or mobile.

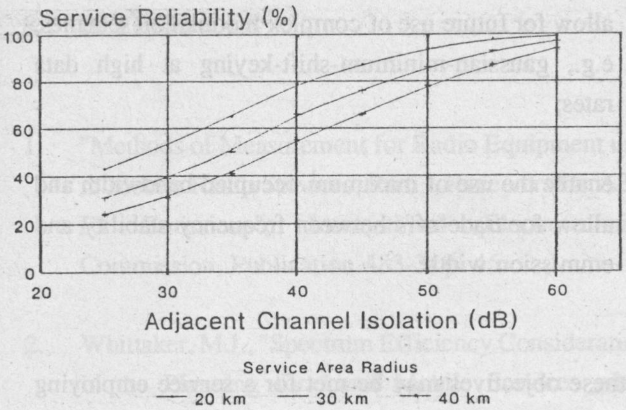

Figure 1 Adjacent channel isolation versus service reliability for a fixed service with a 10 dB protection ratio.

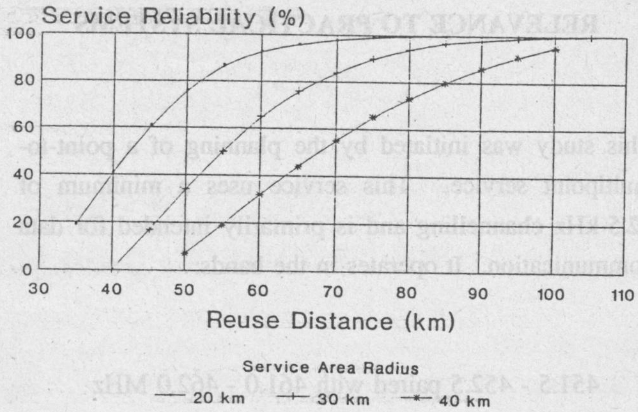

Figure 2 Re-use distance versus service reliability for a fixed service with a 10 dB protection ratio.

The fixed service reliability versus adjacent channel isolation is plotted in fig. 1 for several service area radii. The method of calculation is described in reference 2. The service reliability is that for total service area and not the edge of the service area. The minimum protection ratio chosen for these curves is 10 dB. This protection ratio represents a grade of service bit error rate (BER) of approximately 0.001 for data with two states. With an adjacent channel isolation of approximately 50 dB and a service area radius of 20 km that grade of service or better will be achieved for 95% of locations in the service area, i.e., a service reliability of 95%.

4 CO-CHANNEL INTERFERENCE

For co-channel interference the variables are:

re-use distance,

minimum protection ratio,

service area radius,

fixed or mobile.

The fixed service reliability versus re-use distance is plotted in fig. 2 for a number of service area radii. Again the minimum protection ratio chosen is 10 dB. With a service area radius of 20 km a re-use distance of 60 km will result in a service reliability of about 95%.

The co-channel interference is calculated using the system model for a hexagonal placement of co-channel base stations about the wanted station. With this assumption there is no account taken of the irregular distribution of population or prime site locations. For example, in Australia a model using only two co-channel interferers may be more appropriate due to the high population density along the coastal area. Therefore the results in fig. 2 represent worst case.

5 THE SPECTRUM PLANNING PROCESS

The first stage in the spectrum planning process is to choose the system model for the service being considered. This means selecting the transmitter power, antenna type, antenna height and service reliability which represent the majority of systems. These parameters may be used together with reasonable propagation models to estimate a nominal service area radius. Once the service area radius is chosen, the necessary adjacent channel isolation may be read from a figure similar to fig. 1 and the minimum distance for frequency re-use may be read from a figure similar to fig. 2. The interference probabilities from each interference mechanism may be taken as independent. In this case the total decrease in service reliability equals that due to co-channel interference plus that due to adjacent channel interference minus their product. Of course there are other practical considerations which also need to be taken into account.

6 RELEVANCE TO PRACTICAL SYSTEMS

This study was initiated by the planning of a point-to-multipoint service. This service uses a minimum of 12.5 kHz channelling and is primarily intended for data communication. It operates in the bands:

451.5 - 452.5 paired with 461.0 - 462.0 MHz

and

853.5 - 854.0 paired with 929.5 - 930.0 MHz.

If a service reliability of about 90% is acceptable for this service then, with reference to figs. 1 and 2, an adjacent channel isolation of 50 dB and a re-use distance of 60 km would seem a reasonable choice. The service area radius upon which this choice is based is 20 km. However, the re-use distance for land mobile services in Australia is currently 100 km. This distance is based more on the distribution of population centres than on a required service reliability. There would not be a significant increase in actual frequency re-use by reducing the re-use distance below 100 km. This argument would also be true for a point-to-multipoint service. Also, by employing a re-use distance of 100 km the limiting factor is adjacent channel isolation and the service reliability is 95% within a 20 km service area. In addition, the use of quasi-simulcast transmitters within the service area for coverage improvement will be assisted by the use of a 100 km re-use distance.

When selecting a limit for transmitter emission in the adjacent channel for the proposed service, there were several objectives. They are to:

(a) require no special compatibility criteria for the use of adjacent channels;

(b) maintain a reasonable service reliability for adjacent services;

(c) allow for initial use of simple modulation schemes, e.g., minimum-shift-keying at low data rates;

(d) allow for future use of complex modulation schemes, e.g., gaussian-minimum-shift-keying at high data rates;

(e) enable the use of maximum occupied bandwidth and allow for trade-offs between frequency stability and emmission width.

All these objectives may be met for a service employing 12.5 kHz channelling by limiting the emission over a given temperature range to -50 dBc in a 10 kHz bandwidth centred on the adjacent channel. Note that for a fixed service, the use of directional antennas by all outlying stations at the edge of the service area but not by those in the centre of the service area will effectively increase the adjacent channel isolation.

This method of analysis is also relevant to land mobile services. For 25 kHz bandwidth services the model adjacent channel isolation is 67 dB and the protection ratio is 5 dB (i.e., about 12 dB SINAD). For an overall service reliability of about 90% the computed results are a re-use distance of 100 km and a service area radius of 40 km. These are the system model parameters at present. For 12.5 kHz bandwidth services where the adjacent channel isolation is 55 dB, the same service reliability equates to a re-use distance of 80 km and a service area radius of 30 km.

For cellular services the service area radius may be 2 km and the re-use distance is about 10 km. For this case the model suggests a service reliability when considering co-channel interference of about 80%. An adjacent channel isolation of greater than 15 dB would provide the same order of service reliability.

7 CONCLUSION

A method of selecting a minimum adjacent channel isolation for a radiocommunication service which is also consistent with the re-use distance for that service is presented. The results are based on a reasonable model for the system and will be of assistance when planning radiocommunication services.

8. REFERENCES

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Michael Whittaker received a Bachelor of Applied Science degree in Physics from the University College of Southern Queensland in 1971. He managed the Nuclear Magnetic Resonance (NMR) service facility at the Research School of Chemistry ANU for ten years and has co-authored several papers dealing with the application of NMR. He received a Graduate Diploma in Electronics from the University of Canberra in 1983 and joined the Spectrum Planning Section of DOTC. He is the author of several papers dealing with frequency assignment automation and the electromagnetic compatibility aspects of spectrum planning. Mr Whittaker is a Senior Member of The Institution of Radio and Electronics Engineers Australia.