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Research on the Coordination of Repeaters Distribution Based on CTCSS

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Abstract

Applying repeaters and CTCSS for frequency transmission will be easier. But how to arrange the repeaters to cover the areas and allocate the CTCSS is one of the most indispensable problems. At first, this paper establishes the model to cover the area. According to previous study, our approach is to tile the region with hexagons inscribed within circles of radius equal to the distance a user's signal will reach effectively. Then, this paper checks the repeaters' usage loads whether the number of them is adequate for large number of users. This paper set five conditions which must be satisfied. And then report the 2 meter band which is close to the information that topic has given. This algorithm is to arrange the frequency division and allocate the CTCSS step by step.

Keywords: *cellular network, out-put&in-put frequency, usage load*

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1. Introduction

With the development of the technology, more and more scientific and technological achievements present in the world bring earth-shaking changes to people's life such as the signal propagation which makes the remote interpersonal communication possible.

However the transmission of the signal is limited by some conditions such as distances. This limitation can be overcome by "repeaters," which pick up weak signals, amplify them, and retransmit them on a different frequency. Thus, using a repeater, low-power users (such as mobile stations) can communicate with one another in situations where direct user-to-user contact would not be possible. However, repeaters can interfere with one another unless they are far enough apart or transmit on sufficiently separated frequencies.

In order to mitigate interference problems, the "continuous tone-coded squelch system" (CTCSS) [1], sometimes nicknamed "private line" (PL), was invented. In radio or wireless telephony, Private Line is a term trademarked by Motorola to describe their implementation of a Continuous Tone Coded Squelch System (CTCSS), a method of using low frequency sub audible tones to share a single radio channel among multiple users. Each user group would use a different low frequency tone. Motorola's trade name (especially the abbreviation PL) has become a generalized trademark for the method. General Electric used the term 'Channel Guard' to describe the same system and other manufacturers used other terms. A later digital version of Private Line is called Digital Private Line, or DPL.

In many such networks, the nodes are homogeneous [2], and a node can simultaneously play the roles of source node, sink node, and relay node; a typical example is a cellphone. In other scenarios, the relay nodes usually do not initiate communications but only help communications between other nodes. For example, in amateur radio, repeaters can be considered relay nodes, and hams usually carry their own radios; the functionalities of repeaters and radios are different, as are their power specifications.

Pan et al. [3] proposed a two-tiered relay network model, where base stations are considered low-power users and some inter application nodes play the role of relay nodes. However, they did not address the issue of covering all users. Gupta and M.Younis [4-5] considered fault-tolerant and traffic load balance problems in a two-tiered relay network model but did not address the placement of relay nodes. Target al. proposed two algorithms for placing the fewest relay nodes.

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Those works differ from ours because in a more general scenario the capacity of a repeater and interference among nearby repeaters should be taken into account. We propose a model in which each repeater can simultaneously manage at most C users and two nearby repeaters interfere with each other if their transmitter frequencies are close and they share the same private-line tone.

2. Model of Covering the Area

In this part, our goal is a solution with the minimum number of repeaters. Although every user is covered by at least one repeater, the user's signals may not reach the desired position in Γ, since the coverage of a repeater is also limited and the solution does not guarantee a multi-hop path through several repeaters to reach the desired position. Ignoring the small area that can be reached directly by a user without the help of a repeater, the reachable area Sr(ui) of user ui is the area in Γ that can be covered by at least one reachable repeater of ui (each repeater covers a circle with radius R). The set of reachable repeaters Rr(ui) for ui consists of:

1) Repeaters directly reachable by ui (i.e., the repeaters located within the circle with radius r and centered at ui)

2) Repeaters reachable through links in Err from the directly-reachable repeaters.

We calculate the communication ranges for repeaters and users, as well as the repeater's capacity, using Shannon's information theory. Taking into consideration mobility of users, we show that continuous approximation of the distribution of users' locations is necessary to address the problem. We present a solution with repeaters arranged in a cellular network.

Repeater's Capability [6]:

$$L_{fs}(dB) = 32.45 + 20\log_{10} d_{Km} + 20\log_{10} f_{MHZ} \quad (1)$$

According to the previous study [2], Covered by the node disc model, this problem can be abstracted as: For the area A graphical F, if the radius r of the circle to cover stitching these round, at least to the number of this circle in order to completely cover graphics. It is contemplated, no matter how small the radius r of the circle of an area covering impossible vulnerability coverage without duplication. The solution of the problem can only give way to the completion of the minimum number of regular polygons repeat smallest vulnerability coverage.

We can determine that the adjacent common coverage area of the two circles to the percentage of the total area of a circle is smaller, the the required regular polygon number is less. Regular hexagon is to use at least one node may cover the maximum area of the graphic.

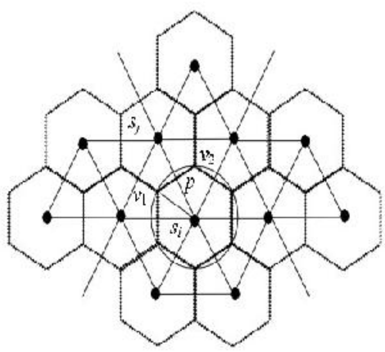

Figure 1

Coverage model based on the regular hexagonal node made regional coverage, without considering the boundary conditions, no vulnerability coverage adjacent seven-node configuration of the area covered by the clusters of nodes and is distributed around the six clusters of nodes, and this can be promotion to the entire coverage area. Therefore, based on regional coverage of the regular hexagon node coverage model, the regular hexagon stitching Figure is aware overlay node, a regular hexagon center point and network connectivity covering close to six regular hexagons constitute a central point of connection nodes Figure.

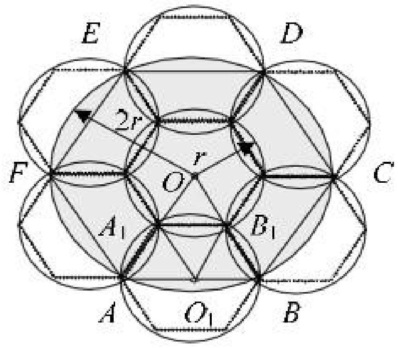

Figure 2

Based on regular hexagon node coverage model of regional coverage, the central node of layer 0 and drill denoted as 1, 2 layer outward, the vulnerability coverage area:

$$A_c = \frac{3\sqrt{3}r^2}{2}(3L(L+1)+1), L = 0,1,\cdots \quad (2)$$

The minimum repeated coverage area is:

$$A_{K\min} = (3L(L+1)+1)(\text{®} - \frac{3\sqrt{3}}{2})r^2 \quad (3)$$

The minimum sensor nodes are:

$$N_{\min} = 3L(L+1)+1, L = 0,1,\cdots \quad (4)$$

The minimum coverage based on a two-dimensional area the regular hexagon node coverage model made repeated at least vulnerability coverage. And the minimum coverage nodes are called the covering number. Hexagonal node coverage model number of covered area within the two-dimensional area:

$$n = \frac{A_q}{A_s} = \frac{A_q}{3\sqrt{3}r^2/2} \quad (5)$$

Where n is the total number of deployed sensor nodes; A_q is monitoring area; A_q is the coverage area of the regular hexagon node coverage model for a single node.

According to a general signal coverage of the relay station radius r = 7.9km [6], we can calculate the relevant parameters of the relay station. So, the area of 40mile radius circular is: $S = \text{®} R^2 = 195.9674km^2$

When the entire circular area covered by the relay station, the relay station without loopholes coverage area of larger area than the entire circular area:

$$\begin{cases} Ac > S \\ 3\sqrt{3}/2r^2(3L(L+1)+1) > S \end{cases} \quad (6)$$

So, we can determine the L: $L \geq 90$

Then, we find that there are 5 more hexagons. Using matlab to describe the results and Figure 3 shows it.

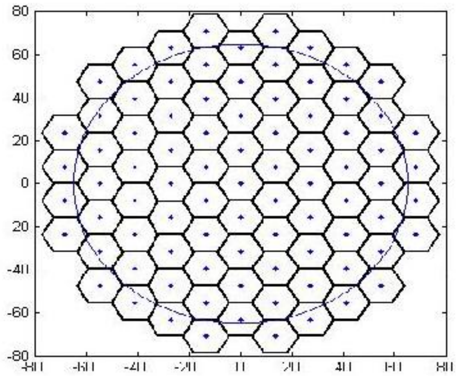

Figure 3

So, firstly we determine to use 85 hexagons to cover the area.

3. Model of Checking the Usage Load

Four conditions must be satisfied. To check the system usage load, we list the constraints.

1) The repeaters' capability areas must cover the whole area.

2) The frequency 145-148MHz must be divided properly.

3) The private-line (PL) tone $n_{PL} \leq 54$ and it must obey the rules.[7]

4) The number of repeaters must be adequate to accommodate 1,000 simultaneous users.

According to the data from the topics, we find that this referred to as the "2 meter" band, which is most often used for FM repeater operations (listed in order of popularity).

"Within these frequency ranges, "standards" have been created as to what frequencies can be used for repeater transmit (output) and receive (input). In most cases, FM (frequency modulation) is used with repeater operations. The most popular transceivers available today will either be "2M only" or "2M/440 dual-band", with the occasional model offering three or even four bands of operation" [7].

Table 1

The type of band	Frequency	Standard offsets	Channel spacing
2 meter band	144-148MHz	600KHz	12.5KHz

In order to divide the output/input frequency of repeaters, we refer to the references and decide the results [7]:

Output: 145 to 145.6 MHz;146.2 to 146.8 MHz;147.4 to 148 MHz

Arrangement

Step1: The first relay station ID:

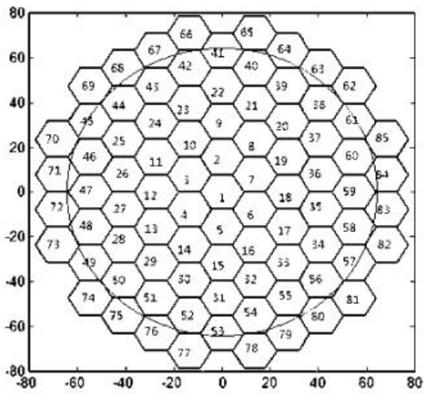

Figure4

Step2: We either take a start from the No. 1 relay station to 4-3-2-7-6-16-17-18-19 … the law of clockwise and counterclockwise alternately. First does not consider the outermost missing 6. Finally 53-31-15-1, form a cycle and the missing angle at 4 to form a loop around a few. Issued such a relay station from any lap can always reach the destination it going.

Attention: 1) Arrangements Note adjacent frequency is not the same. 2) Downlink frequency is arranged in accordance with the principles of 600KHz up and down.

Table 2

Repeaters	1	2	3	4	5
Frequency	146200-146800	147400-146800	146800-146200	145600-146200	146800-147400
Repeaters	6	7	8	9	10
Frequency	147400-148000	148000-147400	146200-146800	145600-146200	145000-145600
Repeaters	11	12	13	14	15
Frequency	145600-145000	146200-145600	145000-145600	145000-145600	145600-145000
Repeaters	16	17	18	19	20
Frequency	146200-145600	146800-146200	147400-146800	146800-147400	147400-146800

4. Model of Changing the Users to 10000

This paper assumes that disposed channel interval is 12.5kHz [7], a relay station within 600kHz width of the spectrum, and thus can only accommodate a maximum of 48 users.

Then, we get a relay station can accommodate up to 48 users, 10,000 are not enough, at least, need to 10000 / n = 209 relay station.

Arrangement

Step1: First in the original place of the relay stations and then to arrange for a relay station, a relay station arranged in the middle of each of the two relay stations.

Step2: The newly added to the original address of the relay station relay station has originally the same frequency of the repeater station, and includes upper and lower rows. Next consider subsonic and if no new plus relay station, relay station to determine the frequency of the first arrangements using only six figures CTCSS frequency corresponds, so only need six CTCSS enough.(Originally not subsonic does not interfere, but behind the new plus the relay station will interfere with, so to add CTCSS)

Step3: Next, the arrangement on the original relay station basis then built a relay station of the case as long as the newly added relay station and it in the region original that relay station can connect to, this will be able to and the other original relay station communicating, thus it emitting sub audio. To the same accepts the relay station and the original sub-audio. In this case, the use or the original six sub-audio and do not increased. Next, consider again accept sub-audio CTCSS between adjacent can, similar to the three-color problem, so just plus three sub audio.

In this case, we use 9 kind of sub-audio.

Step4: Next, in consideration of the increase of the relay station in between every two, send Asia tone front of the same, and two relay stations and the original one of the acceptance of the same sub-audio, and no increase in the sub-audio. Not consider the link between the relay station and the new addition to accept CTCSS similar to the three-color problems [8], just add three to it.

With a total of 9 +3 = 12 CTCSS, we obtain the results. The number of repeaters is 209.

5. Model of the Mountainous Areas' Condition

The propagation of radio waves along the hills, due to the adverse effects of the terrain, to generate additional losses the called "topography loss.".

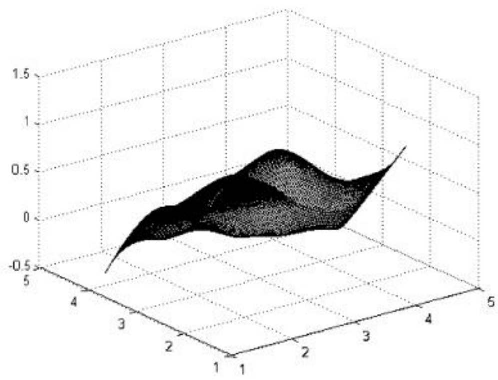

Figure 5

According to the physical characteristics of the propagation path, no more than two conditions:

1) Radio wave propagation between two points, did not block the radio waves between two points on the hills of the direct path. See Figure 6.

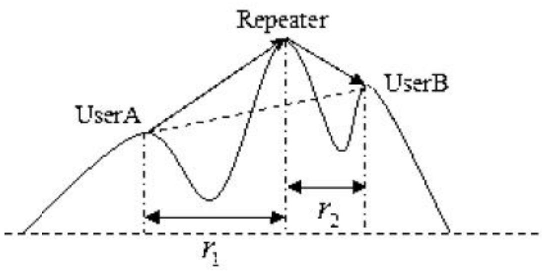

Figure 6

2) The middle hills block the direct path of the radio waves, radio waves can only bypass the top of arrival at another point. See Figure 7.

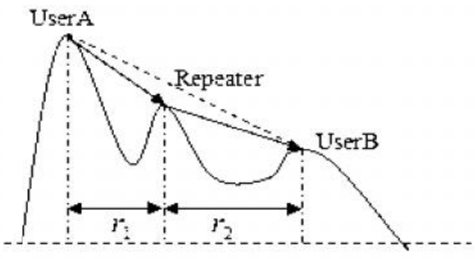

Figure 7

Both cases the hills on the airwaves will be losses, according to the number of two o'clock asked hills, can be divided into single peak loss, loss of bimodal loss and multimodal. We can first establish a simple algorithm, again to unravel a complex algorithm.

The following discuss the single peak loss calculation problem.

In electromagnetic theory, radio waves over obstacles relative to the to field strong E/E0 and terrain loss L can be expressed as:

$$E/E_0 = Fe^{\Delta¤}(0 < E/E_0 \le 1) \quad (7)$$

$$L = 20\log(F) \qquad L \le 0 \quad (8)$$

E_0 is the field intensity of the radio wave propagating in free space, F is the diffraction coefficient Δ is the reflected wave or a diffracted wave with respect to the phase difference in terms of the path of the direct wave.

$$F = \frac{S+0.5}{\sqrt{2}\sin(\Delta¤ + ®/4)} \qquad (0 < F \le 1) \quad (9)$$

$$\Delta¤ = \tan^{-1}\left(\frac{S+0.5}{C+0.5}\right) - \frac{®}{4} \quad (10)$$

Where C and S are the Fresnel integral. v is the dimensionless parameter.

$$V = -h\sqrt{\frac{2}{ª}\left(\frac{1}{¥_1} + \frac{1}{¥_2}\right)} \quad (11)$$

According to analysis above, we can obtain:

1) H = 0, the direct wave is just passing. In this case $E/E_0 = 0.5$. The electric wave field intensity attenuation half; Only when the hills below a certain level of direct wave so that V =0.8 not wave attenuation:

2) When V> 0.8, the theoretical formula is clearly applicable, according to the actual situation lossless (L = 0dB), this time can be regarded as:

3) ª constant, h the more people, the smaller V, when E/E_0 is smaller (the loss (L) bigger)

4) h>OH 'timing. ª smaller, then V is smaller, when the E/E_0 is smaller (loss (I) greater).

We can approximate to the following segmented vertical

$$\begin{cases} L(0) = 0dB \qquad V > 0.8 \\ L(1) = 20\log(0.5 + 0.62V) \qquad 0 < V \le 0.8 \\ L(2) = 20\log(0.5e^{0.95I^{-}}) \qquad -1 < V \le 0 \\ L(3) = 20\log(0.4 - \sqrt{0.1184 - (0.1V + 0.38)^2}) \qquad -2.4 < V \le -1 \\ L(4) = 20\log(-0.225/V) \qquad V < -2.4 \end{cases} \quad (12)$$

The bimodal loss even multimodal loss in turn can be obtained for each peak caused by wear and tear, and then a simple sum that was:

$$L_A = L + L_1 + L_2 \quad (13)$$

In view of the role of the peaks of the signal loss, cho known mountain will affect the signal propagation of the relay station, directly affects the relay station coverage radius Let L peaks impact coefficient is B, the radius of the signal coverage of the relay station in the mountainous:

$$R_m = \quad \times r = 0.5 \times r = 7km \tag{14}$$

In this issue, the entire circular area covered by the relay station and the relay station vulnerability coverage area is larger than the entire circular area:

$$\begin{cases} Ac > S \\ 3\sqrt{3}/2R_m{}^2(3L(L+1)+1) > S \end{cases} \tag{15}$$

Installed within a circular area of the relay station is the minimum number of L takes the minimum value 6, thereby obtaining the minimum number of relay stations of $N_{min} = 31(L + I) + 1 = 127$

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