The Adaptive Long-Distance HF Broadcasting System Based on Backscatter Technique

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Abstract We put forth a project, that is: using the backscatter technique to realize adaptive long-distance HF broadcasting system in order to improve the quality of HF broadcasting. Then, we analyze errors of the system due to the deviation of the ionospheric parameters' prediction. From the analysis, we draw the conclusion that our project is feasible. In addition, we point out that we can use frequency-spreading and information-coding technique to acquire more clear ionograms. We also offer a judgment on how to choose the control propagation mode on condition of multihop and the existence of more than one propagation mode on the signals' path.

Key words HF broadcasting, channel, backscatter technique, frequency-spreading, coding

HF (3～30 MHz) broadcasting has many merits such as the simplicity of equipments, low costs and its ability to realize long-distance propagation through the ionospheric reflection. These merits result in its wide use in long-distance broadcasting systems. On the other hand, the ionosphere is random and dispersive medium which varies both with time and space, so HF spectrum is also the most uncertain spectrum. The existence of multihop in long-distance broadcasting through the ionosphere makes it more difficult to guarantee the quality of broadcasting.

With the consideration of improving the quality of long-distance HF broadcasting, we naturally think of the backscatter technique. It has been proven that the backscatter technique can be used successfully in the following two fields: ① To determine hop distance and its variations with time due to different geophysical factors; ② To supervise and to predict working conditions on HF radio circuit.

We briefly introduces the principle of "Adaptive Long-Distance HF Broadcasting System Based on Backscatter Technique" in the first section. In the second section, under the condition of the curve earth and thick QP (quasi-parabolic) curve ionosphere, we reverse signals' ground propagation distance D from group path P' (transmitting time multiplied by c). Then, we put forward a method to use the sharp fronts and level information of the backscatter pulse to determine the controlling propagation mode. We analyze errors from different sources in the fourth section and in the fifth one we introduce how to control the antenna's radiation pattern by changing the number of rows and/or layers of the curtain transmitting antenna, or the feeding phase of each unit. In this article, we prove the feasibility of our project.

1 Realizing the adaptive long-distance HF broadcasting system

The realization of the adaptive long-distance HF broadcasting system by the backscatter techuique can be divided into three steps:

1) The initialization of the system's working

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condition. We know one of the main characteristics of HF broadcasting system is that the change of working frequency is strongly limited. So what we can do is mainly to choose to the beams' elevation angle. The design of HF circuit has had relatively mature methods[1]. It is reasonable for us to use them to initialize the system.

2) The acquiring and processing of the backscatter signal. We can add a modulated pulse in broadcasting signals, and then receive its backscatter signal. After choosing the ionospheric parameters' prédiction model and the electron density distribution model, we can judge the controlling propagation mode from the group path and the level information of backscatter signal and then reverse signals' coverage region from the backscatter signals' group path P'.

3) The real-time supervising and controlling of the system. If the coverage region we reversed from backscatter signals is not consistent with that of the target region, we can use the computer to control the elevation angle of transmitting antenna to guarantee the broadcasting signals' arrival.

2 Getting ground distance from group path information

When deriving the ground propagation distance from the group path, we need to choose certain ionospheric parameters' prediction model and certain electron density distribution model. The consistence of the predicted values and the real values of the ionospheric parameters will affect the system's precision, but we will see later that for long-distance broadcasting system, these errors are acceptable.

The ionospheric parameters' prediction means that values can be obtained from IRI model and characteristic graphs of CCIR. By the way , more and more complex and precise HF predicton models have been developed[2]. If we can combine them with this system, we can expect a better result. As for the electron density distribution model, we choose the QP model with the curve earth and the curve concentric ionophere because of its consistence with real condition and its precise P' and D expressions.

In QP model, the most important expressions are[3]:

$$P'(f,f_c,r_b,r_m,\beta_0) = 2\{r_b\sin\gamma - r_0\sin\beta_0 + [-r_b\sin\gamma - B\ln((B^2-4AC)/(2Ar_b+B + 2r_bA^{0.5}\sin\gamma)^2)/(4A^{0.5})]/A\}$$

$$D(f,f_c,r_b,r_m,\beta_0) = 2r_0\{(\gamma-\beta_0) - r_0\cos\beta_0 \times \ln[(B^2-4AC)/(4C(\sin\gamma + C^{0.5}/r_b + B/(2C^{0.5}))^2)]/2C^{0.5}\}$$

Where

$A = 1 - 1/X^2 + (r_b/Xy_m)^2$

$B = -(2r_mr_b^2)/(X^2y_m^2)$

$C = (r_mr_b)^2/(Xy_m)^2 - r_0^2\cos^2\beta_0$

$X = f/f_c$ ($f_c = (80.6N_m)^{0.5}$ is the critical frequency)

N_m = maximum electron density(N_e)

r_m = radial distance from earth center to where $N_e = N_m$

r_b = radial distance to the ionosphere base

y_m = layer semithickness

β_0 = elevation angle

γ = $\arccos(r_0\cos\beta_0/r_b)$ is the angle of ray at the bottom of the ionosphere

we can see that when r_m, r_b, X are fixed, P' and D are just the function of β_0. So we can get the relations of P', β_0 and D, and then D from P'.

3 The judging of controlling propagation mode

In HF broadcasting system, it is important to judge the controlling propagation mode. This can be obtained by two steps:

1) To acquire clear backscatter ionograms using PN coding technique. Backscatter signal is very weak after ground scatter, so the acquisition of useful signal is very important. With the great improvement in information coding and digital signal processing technique, it is possible for us to acquire highly definite backscatter ionograms. In our STUDIO system, we will use PN-coding and spectrum-spreading techniques and will be able to acquire clear 3-hop signal with relatively small transmitting power. This provides a solid base for the recognition of backscatter ionograms.

2) To judge the controlling propagation mode. Because the ground distance is much larger than the height of the ionosphere in long-distance prop-

agation paths, signals of those paths, which reach the region around a certain distance, will all lie in a very close region on time axis. Since the power loss due to the ground scatter is much larger than those from any other factors, it is reasonable to choose the one with the strongest signals in each concentrated signal region on time axis as the controlling propagation mode.

4 Error analysis

4.1 Errors from the differences between the predicted and real value of h_mF_2

Because when the elevation angle is smaller than 2°, the radiating character of antenna is very bad, we choose $\Delta_{min}=2°$. We also choose $h_mF_{2,max}=450$ km, and $y_m=0.4\ h_mF_2$, $X=2.0$. For different h_m, we can get signal's P' corresponding to Δ_{min}. Then we can calculate the ground distance D corresponding to this P' on the condition of $h_mF_{2,max}$. We compare this D with the one on the condition of h_m and P'. D_e is the error from the differences between the predicted and real value of h_mF_2. The differences are the biggest ground distance errors. The result is shown on Fig. 1.

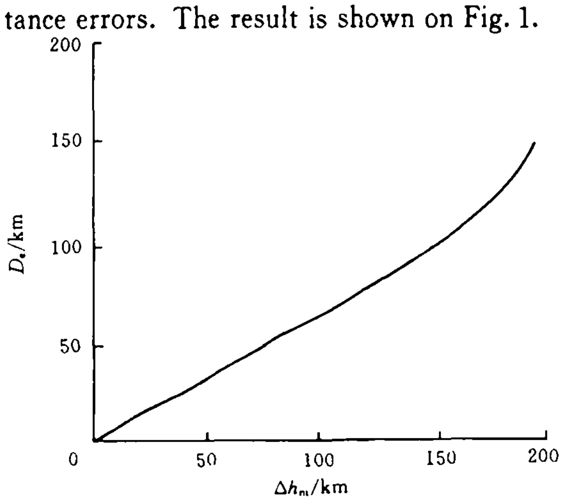

Fig. 1 Errors from the differences between the predicted and real value of h_mF_2

$h_mF_{2,max}=450$ km, $y_m=0.4\ h_m$, $X=2.0$

From it we can see that Δh_m is greater than ΔD. So the ground distance error in each hop is about 100 km, and this error is tolerable in the long-distance broadcasting system.

4.2 Errors from the existence of the different propagation modes

1) The existence of reflection from E region

We can deal with this case according to the method above. Since E region is much lower than F_2 region, this case will lead to larger errors according to our result above, and the propagation distance through it is much shorter than those through F_2. In the long-distance broadcasting, this mode is not the controlling propagation mode we are concerned about in most cases.

2) The presence of E_s layer and the M propagation mode

Fig. 2 shows the errors of D under the conditon of $h_mF_2=350$ km, $X=2.0$, $h_mE_s=100$ km. It is clear that for the long-distance propagation, the error of ground distance is very small.

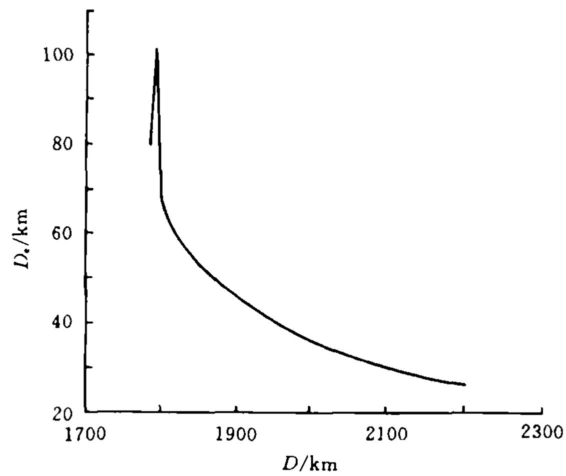

Fig. 2 Errors from the existence of the different propagation mode

$h_mF_2=350$ km, $y_m=0.4\ h_mF_2$, $X=2.0$

5 The real-time control of antenna's elevation angle

As we have pointed out before, the system's adaptability is gained by the real-time control of the transmitting antenna's elevation angle. In long-distance HF broad casting, curtain dipole antenna is most widely used. According to antenna theory, the more rows the antenna has, the thinner the radiation pattern in the horizon plane, and the more layers it has, the lower the elevation angle and the thinner the radiation pattern in the vertical plane. In addition, we can also control the radiation pattern of transmitting antenna by controlling the feeding phase of each dipole. By the use of computers, we can realize the real-time control of antenna.

6 Conclusion

From the analysis and results above, the conclusion is clear. Under the present technique level, we have the ability to realize Adaptive Long-Distance HF Broadcasting System with pulse coding and the ionospheric backscatter technique. This system will be able to apply real-time control into HF broadcasting system and improve the quality of HF broadcasting greatly.

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A UTD SOLUTION FOR THE RADIATED FIELD FROM MONOPOLE ON A CONDUCTING CYLINDER SURFACE WITH A DIELECTRIC COATING

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Abstract A canonical problem is investigated for high frequency electromagnetic radiation from a monopole on a conducting cylinder with coating. At first, the exact solution of this problem is given in terms of Dyadic Green's function method. Then, using Watson transformation and high frequency asymptotic approximate technique to the exact soluton, a UTD soultion is obtained. The radiation field excited by a monopole is expressed in terms of the compound Fock's functions (CFF), which reduce to the geomertrical optics result in the deep lit region and the creeping waves in the shadow region.

Key words conducting cylinder with a dielectric coating, monopole antenna, high-frequency approximate technique, diffraction theory of convex surface, compound Fock function