Fast Reconstruction Method of Reflector Antenna Panel Temperature Field Based on Structural Thermal Analogy

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At present, with increasingly wide applications of reflector antennas in astronomical observation, deep space exploration, satellite communications and military defense etc., the aperture of the reflector antenna is also getting larger and larger, the frequency band is getting higher and higher, and the reflector surface becomes more and more accurate. However, the exposed antenna in the environment is affected by various boundary conditions for a long time. In particular, the thermal deformation of the reflector antenna under the influence of solar radiation seriously affects the performance of the antenna. Obtaining the actual temperature field of the reflector antenna is a prerequisite for getting accurate and real-time thermal deformation information of the antenna.

Therefore, based on the structural thermal analogy of the reflector antenna and combined with the finite element thermal simulation model and the actual data collected by the temperature sensor, the actual temperature field of the reflector antenna can be quickly reconstructed, which can be used to guide the antenna panel adjustment and improve the antenna synthesis performance.

According to the main panel temperature sensor layout scheme, the panel is divided into a plurality of ring domains in the method. First, formula (1) can be used to calculate the initial temperature field of a certain ring domain at a certain moment

$$t_i^{'} = M_{\varphi}(t_i - T_0) + T_0 \tag{1}$$

Where t_i is the temperature field of the i-th ring domain when matching with the temperature information database, $t_i^{'}$ is the initial temperature field of the i-th ring domain under the current operating condition, and M_{φ} is the rotation factor when the temperature field rotates about the central axis of the antenna aperture plane.

According to the actual value collected by the temperature sensor in the i-th ring domain under the current operating condition and the initial temperature value of the location of the temperature sensor in the i-th ring domain under the current operating condition, we can calculate the analog coefficient of the i-th ring domain of the antenna surface based on the structural thermal analogy characteristics of the antenna:

$$\eta_i = \frac{1}{n_i}\sum_{k=1}^{n_i}\frac{t_{ij}-T_0}{t_{ij}^{'}-T_0} \tag{2}$$

Then the initial temperature field of the i-th ring domain should be corrected by using its own analog coefficient to obtain the actual temperature field of the i-th ring domain. Finally we can reconstruct the actual temperature field of the entire reflector antenna through integrating the actual temperature field in all ring domain. Figure 1 is the application of this method, in which we reconstruct the panel temperature cloud chart of a reflector antenna on the day from 8 am to 17 pm.

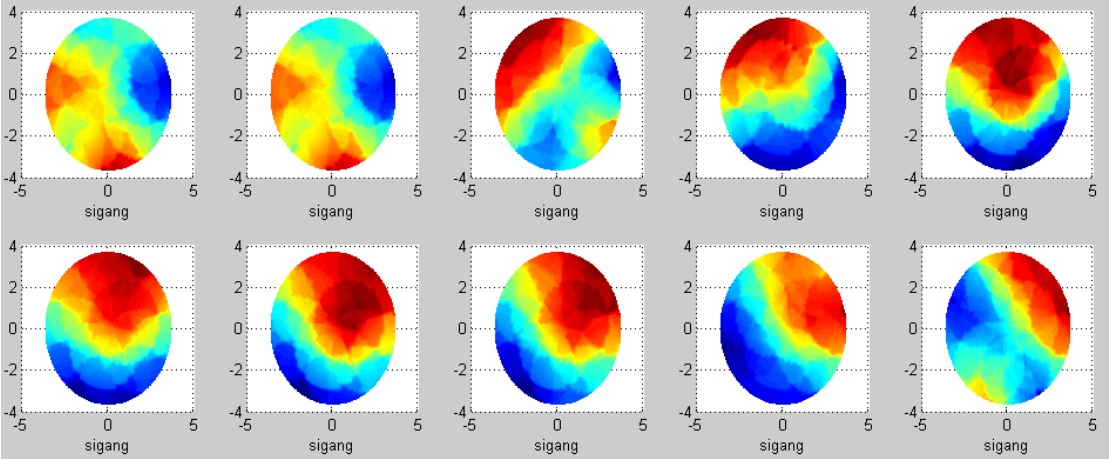
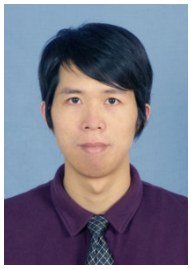


Fig.1 Panel temperature cloud chart



Congsi Wang received the B.S., M.S. and Ph.D. degrees in Electromechanical Engineering from Xidian University, Xi'an, China, in 2001, 2004 and 2007, respectively. Dr. Wang is currently a Professor of Electromechanical Engineering in the Key Laboratory of Electronic Equipment Structure of Ministry of Education, and Vice Director of Institute of Mechatronics, at Xidian University. From 2009 to 2011, he served as a Postdoctoral Fellow at Nanjing Research Institute of Electronics Technology (NRIET), Nanjing, China. From 2012 to 2013, he is a Visiting Scholar at University of California, Berkeley, USA.

His research interests are primarily in the area of Electromechanical Coupling of Electronic Equipments with emphasis on the modeling, influencing mechanism, design and application of structural-electromagnetic-thermal coupling of antennas including phased array antennas, reflector antennas, deployable antennas and so on. He has published authored or co-authored over 80 technical papers and one book, and holds 18 licensed China patents and 19 registered software copyrights. He received many awards including the 2013 and 2008 State Science and Technology Progress Award (Second Class), the 2014 Shaanxi Province Science and Technology Award (First Class), and the 2011 Outstanding Team Award for National Science and Technology Plan Execution, and the 2012 Technological Invention Award of High Education (Second Class), Ministry of Education of China. He was also the recipient of the 2015 National Natural Science Foundation for Excellent Young Scholars of China, the 2014 Young Scientists Award of International Union of Radio Science (URSI), the 2009 New Century Excellent Talents in University of Ministry of Education of China, and the 2011 Second Xi'an Youth Science and Technology Talents Award given by the Xi'an Municipal Government.