Research on BRATUMSS System of Detecting Transmission Model and Breast Tissues Target Spectrum Distribution

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Abstract - BRATUMASS system uses the difference on dielectric constant between breast cancer tissues and normal breast tissues from target tissues microwave response back scatter echo to screen the various tissues. The characteristics of detection object can be determined through analysis of characteristic of echo. The paper also forwards the transmission loss model depending on the characteristics of the system detection data, and gives fitting analysis results of in vivo real data.

Keywords: BRATUMASS, Transmission Loss, Echo Coefficient, Dielectric Constant

1 Introduction

The environment of microwave propagation determines the transmission loss. For the environment is too complex, people usually summarize empirical model in different environments based on testing data when establishing microwave propagation prediction models. BRATUMASS system makes use of the difference on dielectric constant between breast cancer tissues and normal breast tissues which obtain object tissues back scatter echo through of microwave irradiation. By analyzing echo characteristics, and thus determine the system of characteristics of detecting targets. Since microwave signal power launched by the BRATUMASS system is about 6mW which is received by receiving antenna after transmission in sounding target space. In a relatively longer distance, attenuation becomes the main factor of sampling data quality. This paper is to solve the estimation problem of signal transmission loss of BRATUMASS system and to identify region of tissues echo in power spectrum and provide useful reference for the separation of echo. BRATUMASS system transmission loss model is proposed in analysis of in vivo real data and gives the corresponding valuation formula.

2 BRATUMASS System Transmission Loss Estimation Model

Figure 1 is BRATUMASS system experimental model and antenna structure at present. Zheng, S[1] and others have simulated the electric field distribution within the breast in the electromagnetic field of 1.5GHz and prove that there is a huge difference of the electric field distribution between the breast model of uniform tissue distribution and malignant breast tissues. The transmission of electromagnetic wave within the breast is attributed to near-field problems. Considering the vicinity region of transmission antenna, all possible transmission patterns have been encouraged and there are many high-order modes each of which has its own particular transmission direction and the transmission path. In theory, mode number is infinite, so fast fading phenomenon is very obvious. After a propagation distance high-order mode is almost faded out, then enter the transfer mode mainly based on the base band transmission in which attenuation has become slow down obviously.

BRATUMASS system adopts FM microwave, and the center frequency is 1.5GHz. The propagation velocity of microwave in medium of the detection region (breast tissues) is

\[ v = 0.766 \times 10^8 \text{m/s} \]  

and wavelength is

\[ \lambda = \frac{v}{f} = \frac{0.766 \times 10^8 \text{m/s}}{1.5 \times 10^9 \text{Hz}} = 0.0510 \text{m} = 5.1 \text{cm} \]

In the BRATUMASS detection environment, detection target is located in near-field where guided propagation has not been established and propagation of electromagnetic wave here is the multimode, which is similar to propagation mode in free space, so electromagnetic wave mode in free space can be used for prediction. In free space we have

\[ 10 \log \frac{P_r}{P_i} = 10 \log \left[ \frac{G_i G_r \lambda^2}{(4 \pi)^2 d^2} \right] \]

(1)
Where, $P_t$ is the transmission power, $P_r$ is the power of receiver, $G_t, G_r$ is seperately gain of transmitting antenna and receiving antenna, $d$ is line-of-sight distance between transmitting antenna and receiving antenna, unit is m. $\lambda$ is electromagnetic wavelength, $f$ is electromagnetic frequency, $\text{here adopt 1.5GHz}$. The microwave propagation speed of breast tissues detected by BRATUMASS system is \( v = 0.766 \times 10^8 \text{ m/s} \). Suppose gain of transmitting antenna and receiving antenna are both 1, and then formula (1) can be given as:

\[
10 \lg \frac{P_r}{P_t} = 10 \lg \left( \frac{G_t G_r \lambda^2}{(4\pi)^2 d^2} \right) = 20 \lg (0.766 \times 10^8) - 20 \lg 4\pi - 20 \lg f d
\]  

(2)

Based on the above data, we can obtain the following formula

\[
10 \lg \frac{P_r}{P_t} = -20 \lg d - 47.8214
\]  

(3)

![Figure 1 BRATUMASS System Sketch Map](image)

Figure 1 shows the BRATUMASS System Sketch Map.

The following is the calculation of compensating relationship.

As seen in figure 1, suppose transmission power at transmitting antenna is $P_{t1}$, the power of electromagnetic wave reaching on target surface is $P_{r1}$, the distance between transmitting antenna and target is $d_1$, 2-order (echo power) transmission power on target surface aroused by electromagnetic wave is $P_{r2}$, the power at receiving antenna from echo is $P_r$, the distance between target and receiving antenna is $d_2$. Considered separately from transmitting antenna and receiving antenna, we can obtain:

\[
\frac{P_{r2}}{P_{r1}} = \frac{P_{r1}}{P_{t1}} \times \frac{P_{r2}}{P_{t2}} \times \frac{P_{t2}}{P_{t1}}
\]  

(4)

And $\frac{P_{r2}}{P_{r1}}$ is echo power ratio of target, and that is the logarithm of (4) is:

\[
10 \lg \frac{P_{r2}}{P_{r1}} = 10 \lg \frac{P_{r1}}{P_{t1}} + 10 \lg \frac{P_{r2}}{P_{t2}} + 10 \lg \frac{P_{t2}}{P_{t1}}
\]  

(5)

Substitute (3) into (5)

\[
10 \lg \frac{P_{r2}}{P_{r1}} = 10 \lg \frac{P_{r1}}{P_{t1}} + 10 \lg \frac{P_{r2}}{P_{t2}} + 10 \lg \eta_e
\]

\[
= (-20 \lg d_1 - 47.8214) + (-20 \lg d_2 - 47.8214) + 10 \lg \eta_e
\]

If $d_1 \approx d_2 = d$ then formula above can be simplified as follows:

\[
10 \lg \frac{P_{r2}}{P_{r1}} = 2 \times (-20 \lg d - 47.8214) + 10 \lg \eta_e
\]  

(6)

Considering (6) is the estimation value of object in homogeneous medium, secondary emission signal power of target aroused by microwave is weaker than that of microwave antenna ignoring 2-order dispersion and other factors, relationship between echo signal intensity in detection space of BRATUMASS system and distance is:

\[
10 \lg \frac{P_r}{P_t} = (-20 \lg d - 47.8214) + 10 \lg \eta_e
\]  

(7)

### 3 Simulation Results of BRATUMASS System

In order to validate the above estimation model, this paper adjusts the sampling of system as follows: Place BRATUMASS system combined antenna (shown in figure 2d) at the triangle mark position shown in figure 2a; Place sheet metal of which diameter is 1cm at the ellipse mark position (and the metal $\eta_e \approx 1$). The size of combined antenna and the position of object space are shown in figure 2b and Figure 2c. The base circle size of breast is different depending on different objects. Corresponding data of 14 objects are got. [2]

Figure 3 and Figure 4 show two examples of the curve relationship between responding echo of sheet metal and loss estimation curve. And the distance between the sheet metal and detection antenna are separately 175mm and 122.5mm the (3) curve is attenuation value of estimation by formula (3) for metal material. The (6) curve is the attenuation value of estimation by formula (6).

As shown in Figure 3 and Figure 4, signals of (distance) 100mm-200mm received by BRATUMASS system receiving antenna basically located in the estimation region of (3) and (6). And echo of sheet metal is fairly close to the (3) curve of (3). So, it is basically reasonable to use transmission model in free space to estimate attenuation relationship.
Figure 2. Experimental antenna and position of sampling sketch map in target space. 2a structure of breast, triangle mark point is the position of real data sampling and ellipse mark point is position of sheet metal. 2b. BRATUMASS system testing position sketch map of which red point is the position of real data sampling and green point is position of sheet metal  2C. Sketch map of parts of combined antenna, A is transmitting antenna. B is receiving antenna. 2d. Combined antenna

Figure 5 shows sheet metal echo spectrum of 14 objects detected by formula (5) accords with the estimation of formula (3). Of which the mark $\bigtriangledown$ is the peak value distribution of metal piece echo spectrum.

Figure 3. Echo Power Spectrum when distance between metal piece and detection antenna is 175mm

As seen from the figure 5, the estimation value is close to the distribution of real echo. The echo peak value distribution of sheet metal is close to the estimation of formula (3), which accords with the distribution of $\eta_e = 1$.

Figure 4. Echo Power Spectrum when distance between metal piece and detection antenna is 122.5mm

Figure 5. Sheet metal echo spectrum of 14 objects detected by (5) accords with Estimation of (3), of which the mark $\bigtriangledown$ is the peak value distribution of metal piece echo spectrum

4 Conclusions

According to the theory of near-field transmission, this paper gives the estimation of microwave transmission loss in target space of BRATUMASS system. The echo of sheet metal is close to the ideal value distribution of $\eta_e = 1$ based on the real testing data. Echo of real breast tissues is close to simulation distribution when dielectric constant is between 10.04-14.93. The dielectric constant of normal breast tissue is between 10 and 15 under frequency of 1.5GHz [3], and sheet metal can’t be inserted into living breast for detection because of current conditions. The attenuation can only be estimated by measuring microwave intensity outside. Mode data accords well at distance of beyond $2\lambda$.

The destination of BRATUMASS system is to confirm the distribution information within tissue of breast object. This paper only involves the region location of useful information of echo in the power spectrum, and details of isolation technical of useful information will continue to be discussed in the following articles.
5 Acknowledgement

This work has been performed while Prof. M. Yao was a visiting scholar in Michigan State University, thanks to a visiting research program from Prof. Erik D. Goodman. M. Yao would also like to acknowledge the support of Shanghai Science and Technology Development Foundation under the project grant numbers 03JC14026 and 08JC1409200, as well as the support of TI Co. Ltd through TI (China) Innovation Foundation. And this work is in part supported by National Science Foundation of China grant number 61002003.

6 References

