RESONANCE NEAR-FIELD MICROWAVE DIAGNOSTICS IN DERMATOLOGY

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Abstract

Resonance sensors for noninvasive express diagnostics of biological tissues are developed. The sensor operation is based on the method of near-field microwave sounding. The state of a tissue is estimated by its electrodynamic parameters (dielectric permittivity and conductivity). The capabilities (sensitivity, resolution, etc.) of the measuring systems employed for investigation of skin and differential diagnostics of various dermatoses.

Keywords: Express diagnostics, biological tissues, near-field microwave sounding, skin, dielectric permittivity, conductivity.

1. INTRODUCTION

Pathological and physiological processes in living tissues are usually accompanied by variation of their electrodynamic parameters; hence study of dielectric permittivity and conductivity of bio-objects is of considerable interest for various medical applications.

Diagnostics of skin pathologies without using the hystomorphologic method is required in dermatology. Tissue sampling (biopsy) refers to minor operations and is often undesirable for patients with abnormality in carbohydrate metabolism, vascular pathology, and eruption on unclothed parts of the body (face, neck, and hands).

The aim of the study is to consider the opportunities of resonance near-field microwave sounding for estimation of viability of parenchymal organs in critical states, determination of pathologic processes, differential diagnostics of various dermatoses, and control of medical maintenance.

2. MAIN PART

The method of resonance near-field microwave probing can be explained as follows. The area of a medium located in the near field of a probing electrically small antenna affects its impedance. This feature enables one to provide high spatial resolution. If the antenna is connected to the resonance system as a load, the resonance frequency shift and the Q-factor variation can be used to estimate the electromagnetic parameters of the medium and then the state of the examined object.

Diagnostic probes for passive measurements of the electrodynamic features of parenchymal organs and sensors for investigation of skin of dermatologic patients have been developed. A high-Q microwave resonator placed on a segment of the coaxial line is employed as a resonance system. The eigenfrequencies of the sensors are $\omega_0 \sim 2\pi \cdot 800$ MHz and the Q-factor is Q_0 ~150. The spatial resolution and the sensitivity are determined by the design and sizes of the electrically small antenna.

If Z_0 is the internal impedance of the antenna, Z_{medium} is the impedance of the antenna contacting with the medium, and $Z_{medium}<\rho$ (ρ is the wave resistance of the coaxial resonator), according to [1] one can obtain the equation of the resonance curve $U_{res}(\omega)$ of the sensor

$$U_{res}(\omega) = U_0 \left[16Q_0^2 \left(\frac{\omega - \omega_0}{\omega_0} + \frac{1}{\pi\rho} \operatorname{Im}(\delta Z) \right)^2 + \left(1 + \frac{4}{\pi} \frac{Q_0}{\rho} \operatorname{Re}(\delta Z) \right)^2 \right]^{-\frac{1}{2}}$$

$\delta Z_x = Z_0 - Z_{medium}$ U_0 is the signal amplitude in the resonance curve maximum.

From the equation $U_{res}(\omega)$ one can easily obtain the relation between the resonance characteristics of the sensor and the impedance features of the electrically small antenna

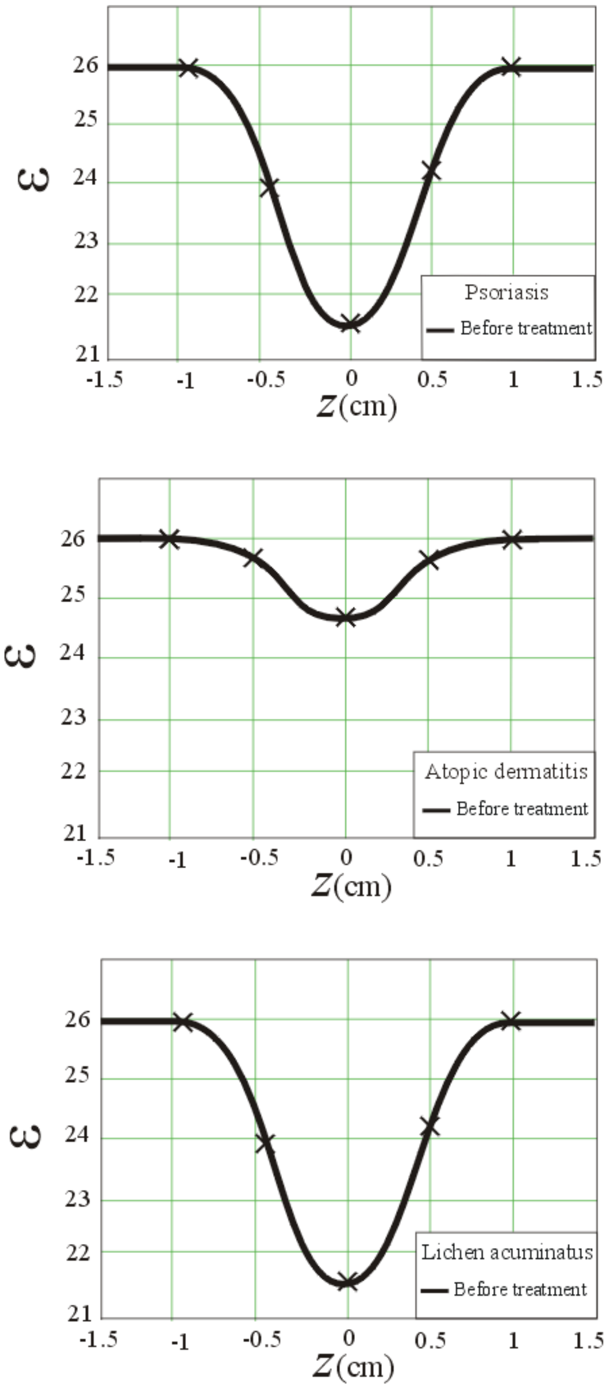

Fig. 1. Dielectric permittivity of skin in the area of a localized pathologic part. Diseases are in the exacerbation stage. The diameter of the focus of disease is 1 cm; the coordinate *Z* is measured relatively to the center of the target affected part.

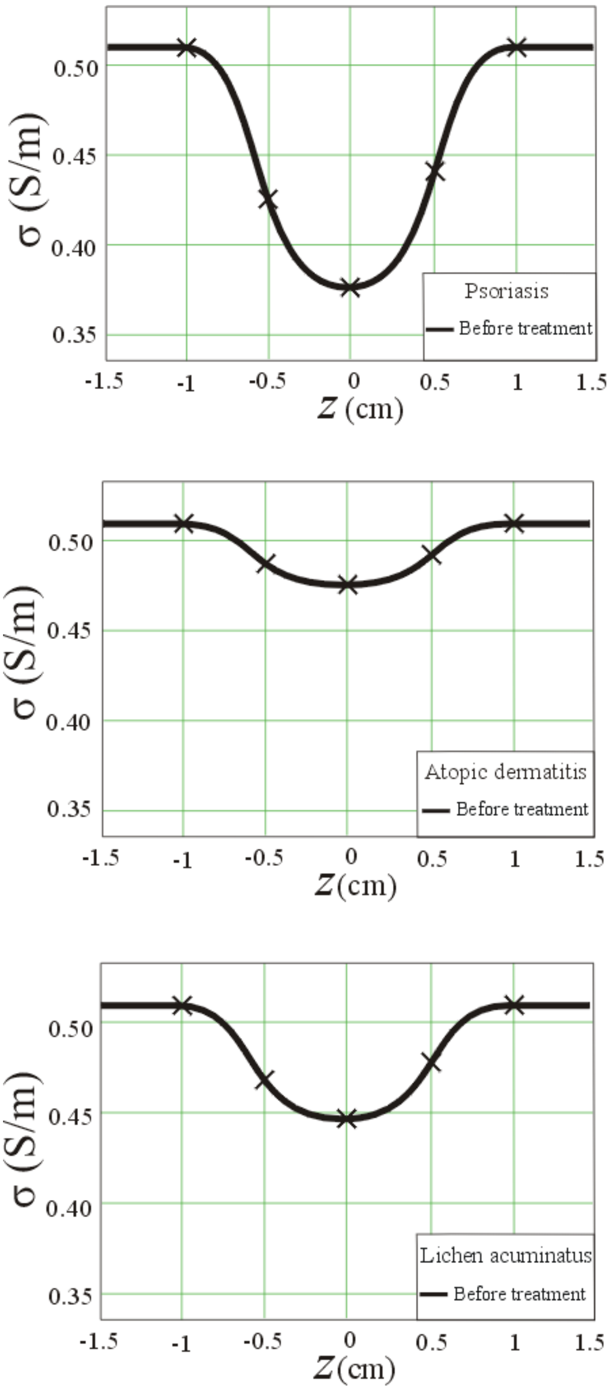

Fig. 2. Conductivity of skin in the area of a localized pathologic part. Diseases are in the exacerbation stage. The diameter of the focus of disease is 1 cm; the coordinate *Z* is measured relatively to the center of the target affected part.

$$\omega_{res} - \omega_0 = -\frac{1}{\pi}\frac{\omega_0}{\rho}\operatorname{Im}\left(\delta Z_x\right)$$

$$\max\left(U_{res}\right) = U_0\left(1 + \frac{4}{\pi}\frac{Q_0}{\rho}\operatorname{Re}\left(\delta Z_x\right)\right)^{-1}$$

Electrodynamic characteristics of skin of 32 cases of psoriasis, 10 cases of atopic dermatitis, and 13 cases of lichen acuminatus (LA) were studied at the Research Institute of Dermatology and Venereology (the city of Nizhny Novgorod).

It is stated that the dielectric permittivity and conductivity of skin of dermatologic patients (cases of psoriasis, atopic dermatosis, and lichen acuminatus) are lower than those of healthy skin. The patients were examined before treatment, in the course of treatment, and after it. As the patients recovered, the dielectric permittivity and conductivity of tissues in the area of the focus of disease in all three groups of patients approximated the values of healthy skin.

In the exacerbation stage, the difference between healthy and damaged skin were more distinct in the case of psoriasis. In the regress stage, the dielectric permittivity and conductivity of tissues in the area of psoriatic focuses of disease were analogous to ε and σ of tissues in the case of atopic dermatitis. Hence in the cases of psoriasis and atopic dermatitis, the method is diagnostically significant only when a disease is active (figure 1-2).

When studying the electrodynamic characteristics of skin in the case of lichen acuminatus, it was found out that if the dielectric permittivities of tissues in the case of psoriasis and in the case of LA coincided, the conductivities in these cases differed by factor of 2.

This permits drawing a conclusion on the possibility of diagnostics in the cases of psoriasis and LA at arbitrary stages of disease (figure 1-2).

3. Conclusion

Therefore, the resonance near-field microwave diagnostics used in dermatology for the first time has demonstrated its diagnostic and prognostic value in study of dermatoses.

4. References

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