Dual Band Microstrip Antenna

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Abstract— In the article a structure of multilayer microstrip antenna operating at frequencies 2.4 GHz and 5.8 GHz have been presented. The antenna structure consists of three dielectric layers and two radiant elements; it is supplied by electromagnetic coupling. Moreover problems occurring in multilayer dual-frequency structures have been discussed in the article.

1. INTRODUCTION

Portable electronic devices more and more boldly enter the everyday life of a modern man. A society uses not only simple mobile phones but also multimedia equipment which makes constant access to the Internet and user's position by GPS system possible [5–9]. It can be assumed that it is transitional stage to integrate many electronic devices with clothes and build a system which will include a lot of elements enabling human contact with the entire world and unlimited access to any information but also monitoring his vital functions and alarming him and suitable services about potential dangers and threats [1, 2].

A fast development of technology of wireless Internet access and requirements of meeting norms imposed on WLAN, WiMAX and other wireless network technologies extort the demand for devices, which apart from reliability and functionality will be characterized by a small size [13, 14]. Since a necessary element of each wireless system is antenna, it forces also on these elements miniaturization as well as possibility of operation in more than one frequency band [3, 4, 11, 12]. Antennas which due to their properties best meet the above requirements are microstrip antennas. This article presents a multilayer microstrip antenna operating in two frequency ranges: 2.4 GHz and 5.8 GHz.

2. STRUCTURE OF ANTENNA

The antenna has two radiant patches located on separate dielectric layers. Each patch is responsible for operation in a different frequency range. Patch located on the middle layer (layer marked with 2) is responsible for operation at frequencies from the range 5.8 GHz, whereas patch placed on the upper layer (3) is responsible for operation of antenna within the frequency range 2.4 GHz. In Figure 1 graphic display of antenna model has been presented with indication of distribution of particular antenna elements.

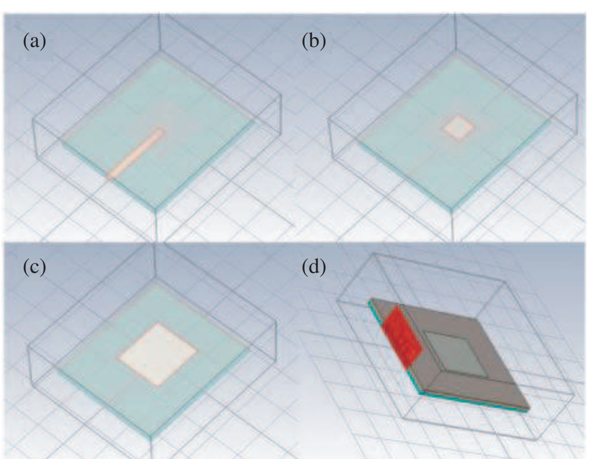

Figure 1: View of location of particular antenna elements: (a) layer 1 and feeder, (b) layer 2 with patch radiating at 5.8 GHz, (c) layer 3 with patch radiating at 2.4 GHz, (d) general view of the whole antenna with charging port.

Figure 2: Finished final antenna models.

For construction of an initial model the following dielectrics have been chosen:
– layer 1: ULTRALAM 2000 ($\varepsilon_r = 2.60$; $h = 1.524\,\text{mm}$),
– layer 2: ULTRALAM 2000 ($\varepsilon_r = 2.40$; $h = 1.524\,\text{mm}$),
– layer 3: Duroid 6202 or Duroid 6200 ($\varepsilon_r = 2.94$; $h = 0.762\,\text{mm}$).

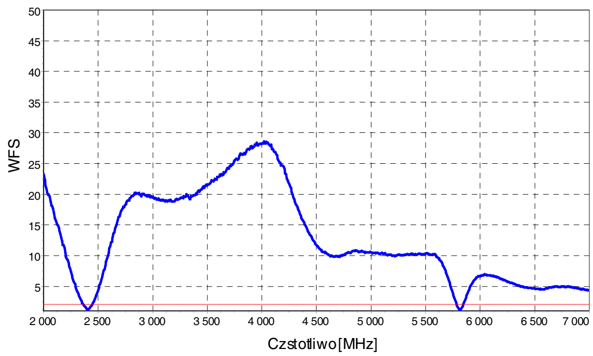

Figure 3: SWR of a single element.

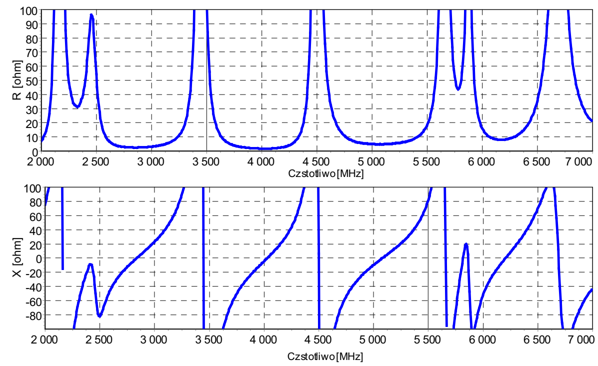

Figure 4: Resistance and input reactance of a single element — measurement result.

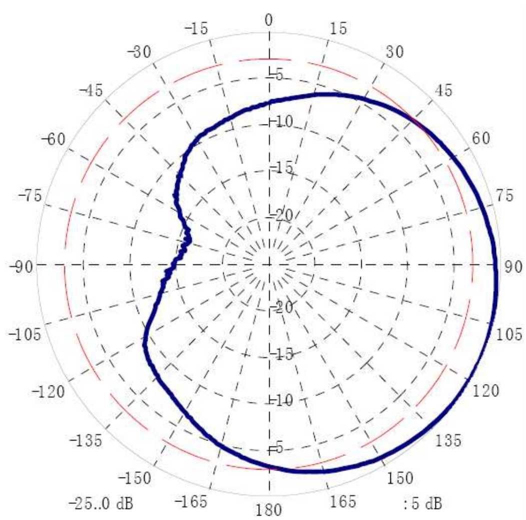

Figure 5: Measured normalized radiation pattern of single element antenna for frequency 2400 MHz.

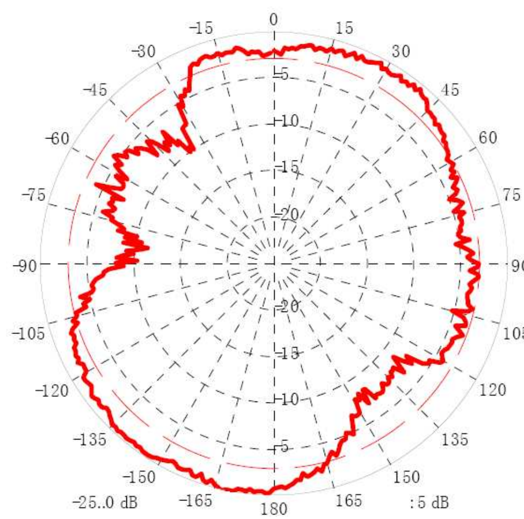

Figure 6: Measured normalized radiation pattern of single element antenna for frequency 5800 MHz.

A built model of microstrip antenna consists of three separate dielectric layers. In the antenna structure dielectrics with close electric and geometric parameters (thickness) have been used. The first layer is dielectric of 1.524 mm thickness and permittivity equal to $\varepsilon_r = 2.6$. In that layer shield was placed from below and feeder line from the top. The second layer is dielectric with the same electrical and geometrical parameters as layer 1. That layer contains radiant element with dimension $14 \times 14\,\text{mm}$ located at the top of dielectric. The third layer is dielectric of 0.762 mm thickness and permittivity equal to $\varepsilon_r = 2.94$, on which the second radiant patch with dimensions $35 \times 32\,\text{mm}$ is placed. It is placed in parallel towards the first radiant patch in layer two. External dimensions of all three layers are the same, respectively: width — 68 mm and length — 84 mm. Total thickness of the antenna is about 3.9 mm.

On the basis of the above presented antenna model two-element and four-element aerial arrays have been constructed. In order to protect the antenna against mechanical defects they have been covered with layer of foamed PVC.

3. MEASUREMENT RESULTS OF ELECTRIC PARAMETERS AND ANTENNA CHARACTERISTICS

In this item an analysis and juxtaposition of results of electric parameters and radiation characteristics of final antenna models have been presented.

For final models of dual-frequency microstrip antennas measurements of such electric parameters as: WFS, S_{11}, input resistance, input reactance and radiation characteristics at selected frequencies from antenna operation range have been conducted. In Figure 2 a view of final antenna models is shown.

The antenna obtains the value WFS < 2 for the following frequency ranges: from 2360 to 2440 MHZ and from 5780 to 5840 MHz. In Figure 7 a built two-element microstrip antenna has been presented.

The antenna obtains the value WFS < 2 for the following frequency ranges: from 2360 to 2530 MHZ and from 5700 to 5840 MHz.

The antenna obtains the value WFS < 2 for the following frequency ranges: from 2340 to 2550 MHZ and from 5780 to 5840 MHz.

Finished dual-frequency microstrip antennas have common frequency ranges of operation (WFS $<$ 2) in particular ranges, respectively 2364–2445 MHz and 5780–5840 MHz. These are frequency subranges included in open-access ISM band. Increasing of the number of radiant elements has led to narrowing of radiation characteristics in V plane.

For the frequency 2340 MHz along with the increase of the number of elements an useful width of radiation beam at level -3 dB has been changing respectively: 125°, 80° and 45°. Whereas in plane H radiation characteristics of antennas, regardless of a number of elements, have not undergone significant changes and kept their shape [15–18].

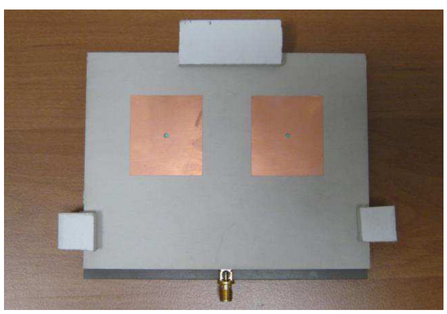

Figure 7: Finished 2×1 antenna models.

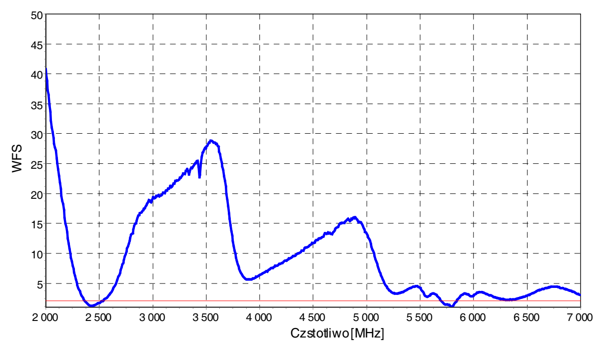

Figure 8: SWR of two-element antenna.

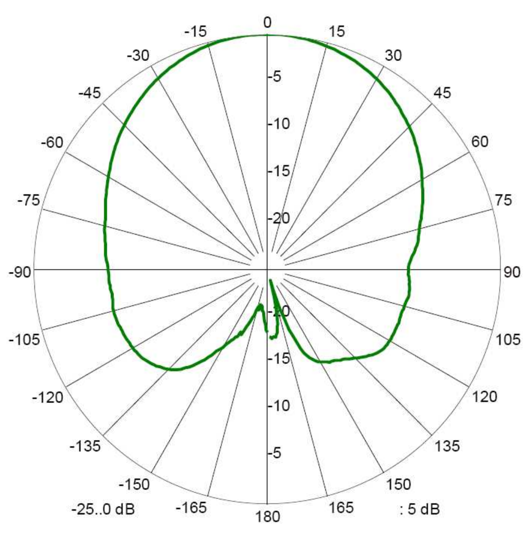

Figure 9: Measured normalized radiation pattern for frequency 2400 MHz (two elements).

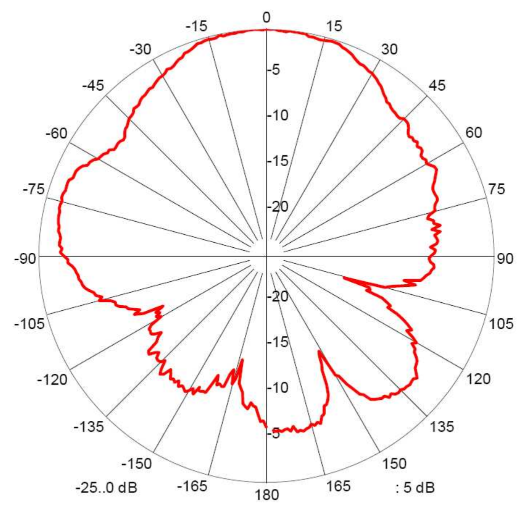

Figure 10: Measured normalized radiation pattern for frequency 5840 MHz (two elements).

Figure 11: Finished 4×1 antenna model.

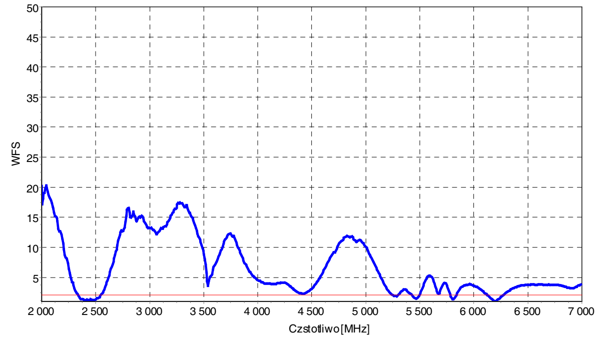

Figure 12: SWR of four-element antenna.

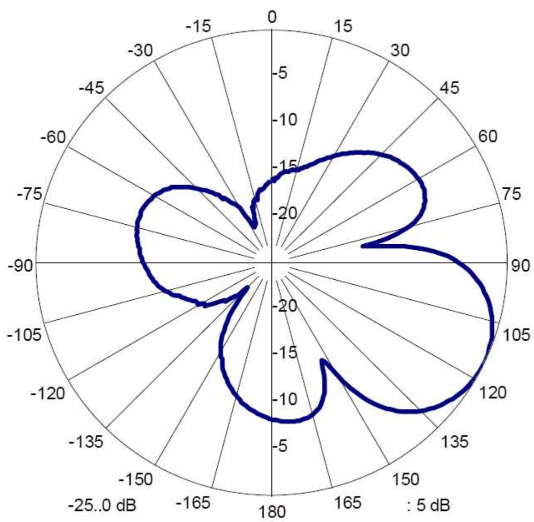

Figure 13: Measured normalized radiation pattern for frequency 2400 MHz (four elements).

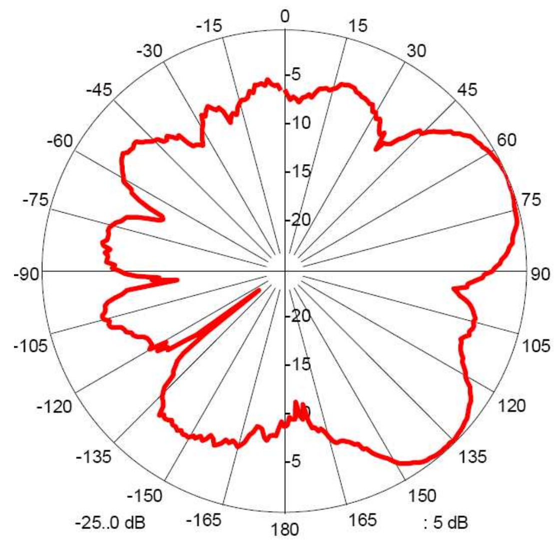

Figure 14: Measured normalized radiation pattern for frequency 5800 MHz (four elements).

4. CONCLUSIONS

While designing dual-frequency multilayer microstrip antennas a few important conditionings should be taken into account. The main condition of designing multi-range antennas is resonant frequency spacing between them. Designing multilayer microstrip dual-frequency antenna with an attempt of obtaining two frequencies, where one is over twice bigger than the other, we will encounter a series of design-construction problems. The first one will be the problem of stimulation of radiant patches for such diverse frequencies caused by significant differences in size of radiant patches. With two-fold frequency difference the surface of patches(radiant elements) will be even fourfold different (with the assumption of using dielectric of a similar value of permittivity in particular layers). Unfortunately it will cause undesirable distortions in radiation characteristics. In such cases, if we place the patch radiating electromagnetic wave of lower frequency over the patch radiating electromagnetic wave of higher frequency, then due to a significant size of the first one, it will be a form of 'shield' at the main direction of radiation causing distortion of radiation characteristics. If we place radiant patches in reverse order — i.e., the patch of a much smaller size is placed at the top, then we will encounter a problem consisting in difficulties with stimulation of this patch to radiate. In this case, the patch of a bigger size will rather effectively hinder stimulation of the patch situated over it to radiate electromagnetic waves.

REFERENCES

1. Gruszczynski, M., M. Wnuk, and L. Nowosielski, "Multisystem microstrip antenna for mobile communications," *2012 IEEE Antennas and Propagation Society International Symposium (APSURSI) Book Series: IEEE Antennas and Propagation Society International Symposium*, 2012.

2. Nowosielski, L., M. Wnuk, and C. Ziolkowski, "Interlaboratory tests in scope of measurement of radio disturbance," *2009 European Microwave Conference*, Vols. 1–3, 288–291, 2009.
3. Piotrowski, Z., L. Nowosielski, L. Zagozdzinski, and P. Gajewski, "Electromagnetic compatibility of the military handset with hidden authorization function based on MIL-STD-461D results," *PIERS Proceedings*, 116–120, Cambridge, USA, July 2–6, 2008.
4. Gajewski, P., J. Lopatka, L. Nowosielski, B. Uljasz, and Z. Piotrowski, "Multimedia transmission over HF links," *IEEE 21st Century Military Communications Conference Proceedings, Military Communications Conference*, Vols. 1 and 2, 45–47, 2000.
5. Bugaj, M. and M. Wnuk, "Optimization parameters of dielectric in aperture-coupled stacked patch antenna on bandwidth," *18th International Conference on Microwaves, Radar And Wireless Communications (MIKON-2010)*, Vols. 1 and 2, 2010.
6. Bugaj, M. and M. Wnuk, "Influence of parameters of dielectric in aperture-coupled stacked patch antenna on bandwidth," *Przeglad Elektrotechniczny*, Vol. 85, No. 9, 50–53, 2009.
7. Bugaj, M. and M. Wnuk, "The influence examination of dielectric parameters on bandwidth in multilayer aperture-coupled microstrip Antennas with utilization the FDTD method," *2008 MIKON Conference Proceedings*, Vols. 1 and 2, 708–711, 2008.
8. Wnuk, M. and M. Bugaj, "Analysis of radiating structures placed on multilayer dielectric," *Computational Methods and Experimental Measurements XIII Book Series: Wit Transactions on Modelling and Simulation*, Vol. 46, 747–755, 2007.
9. Wnuk, M., G. Rózanski, and M. Bugaj, "The analysis of microstrip antennas using the FDTD memod," *Computational Methods and Experimental Measurements XII Book Series: Wit Transactions on Modelling and Simulation*, Vol. 41, 611–620, 2005.
10. Kubacki, R., E. Cwalina, M. Kuchta, and A. Dukata, "Electromagnetic field distribution in the office room and computer enclosure evoked by electromagnetic high power pulses," *Przeglad Elektrotechniczny*, Vol. 88, No. 12B, 209–212, 2012.
11. Kubacki, R., M. Wnuk, and J. Kieliszek, "Fresnel approximations in mathematical expressions of the electric field for base station antennas," *Przeglad Elektrotechniczny*, Vol. 84, No. 12, 190–193, 2008.
12. Kubacki, R., "Biological interaction of pulse-modulated electromagnetic fields and protection of humans from exposure to fields emitted from radars," *2008 MIKON Conference Proceedings*, Vols. 1 and 2, 66–72, 2008.
13. Kubacki, R., J. Sobiech, and E. Sedek, "Model for investigation of microwave energy absorbed by young and mature living animals," *Electromagnetic Field, Health and Environment, Proceedings of EHE '07 Book Series: Studies in Applied*, Vol. 29, 126–132, 2008.
14. Kubacki, R., J. Kieliszek, and A. Krawczyk, "The investigation of influence of the electromagnetic fields emitted from short-wave diathermy to the pacemakers," *Przegląd Elektrotechniczny*, Vol. 83, No. 12, 105–107, 2007.
15. Kubacki, R., J. Sobiech, J. Kieliszek, and A. Krawczyk, "Comparison of numerical and measurement methods of SAR of ellipsoidal phantoms with muscle tissue electrical parameters," *COMPEL — The International Journal for Computation and Mathematics in Electrical and Electronic Engineering*, Vol. 25, No. 3, 691–704, 2006.
16. Dabrowski, M. P., W. Stankiewicz, R. Kubacki, E. Sobiczewska, and S. Szmigielski, "Immunotropic effects in cultured human blood mononuclear cells pre-exposed to low-level 1300 MHz pulse-modulated microwave field," *Electromagnetic Biology and Medicine*, Vol. 22, No. 1, 1–13, 2003.
17. Kubacki, R., M. Wnuk, W. Kolosowski, and J. Sobiech, "New approach to electromagnetic field calculations in the near-field of microwave antennas," *Computational Methods and Experimental Measurements XI Book Series: Computational Engineering*, Vol. 4, 413–422, 2003.
18. Kubacki, R., M. Krukowski, J. Kieliszek, and J. Sobiech, "New computational model of electromagnetic field distribution for predicting of the safety zones in the near-field of microwave antennas," *XIV International Conference on Microwaves, Radar and Wireless Communications, MIKON-2002*, Vols. 1–3, 902–905, 2002.