Research Paper Engineering

New Compact Wearable Meta-material Antennas

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ABSTRACT *Efficient small antennas are crucial in the development of wireless communication systems. Low efficiency is the major disadvantage of small antennas. Meta material technology is used to increase the efficiency of small antennas. Design consideration, analysis, computed and measured results of wearable patch meta-materials antennas with high efficiency are presented in this paper. The antennas electrical parameters are presented. The gain and directivity of the patch antenna with Split-ring resonators, SRR, is higher by 2.5dB than the patch antenna without SRR. The resonant frequency of the antennas with SRR is lower by 5% to 10% than the antennas without SRR.A wideband meta-material stacked patch antenna with air spacing is presented. The antenna bandwidth is around 10% for S11 lower than -9.5dB. The antenna gain is around 10dBi.*

KEYWORDS : Meta-material antennas, Microstrip antennas, Medical Applications

INTRODUCTION

Small antennas are widely used in communication systems. Microstrip antennas features such as small volume and low production cost are crucial in several communication systems. Moreover, microstrip antennas are low profile, flexible and can be used as wearable antennas. Printed antennas are presented in journals and books, as referred in[1-4]. However, small printed antennas suffer from low efficiency. Meta material technology is used to design small printed antennaswith high efficiency. Printed wearable antennas are presented in [2]. Artificial media with negative dielectric permittivity were presented in [5].Periodic SRRand metallic posts structures may be used to design materials with dielectric constant and permeability less than 1 as presented in [5-7]. In this paper meta-material technology is used to develop small wearable antennas with high efficiency.

STACKED PATCH ANTENNA LOADED WITH SRR

A microstrip stacked patch antenna [1-4] has been designed as shown inFig 1. The second step was to design the same antenna with SRR. The antenna feed network is printed onFR4 dielectric substrate with dielectric constant of 4and 1.6mm thick. The radiatoris printed on RT-DUROID 5880 dielectric substrate with dielectric constant of 2.2and 1.6mm thick. The antenna electrical parameters was calculated and optimized by using ADS software. The dimensions of the microstrip-stacked patch antenna shown in Fig 1 are 33x20x3.2mm. The computed S11 parameters are presented in Fig. 2. Radiation patternof the microstrip stacked patchis shown inFig. 3.The antenna bandwidth is around 5% for VSWR better than 2.5:1. The antenna beam width is around 72º. The antenna gain is around 7dBi at 3.9GHz. The antenna with SRR is shown in Fig. 4. This antenna has the same structure as the antenna shown in Fig. 1. The ring width is 0.2mm the spacing between the rings is 0.25mm. Twenty eight SRR are placed on the radiating element.A photo of the antenna is shown inFig. 5. The measured S11 parameters of the antenna with SRR are presented in Fig. 6.The antenna bandwidth is around 12% for VSWR better than 2.5:1. By adding an air space of 4mm between the antenna layers the VSWR was improved to 2:1. However, the air spacing between the antenna layers does not change the radiation characteristics of the antenna. The antenna gain is around 9dBi to 10dBiat 3.65GHz.The antenna efficiency is around 95%. The antenna computed radiation pattern is shown inFig. 7.The antenna beam width is around 70º.The gain and directivity of the stacked patch antenna with SRR is higher by 2dB to 3dB than the patch antenna without SRR.The patch antenna with SRR performs as a loaded patch antenna. The effective area of a patch antenna with SRR is higher than the effective area of a patch antenna without SRR. The resonant frequencyof a patch antenna with SRR is lower by 10% than the resonant frequency of a patch antenna without SRR.

PATCH ANTENNA LOADED WITH SRR

A patch antenna with Split Ring Resonators is presented in this paragraph. The antenna is printed on RT-DUROID 58880

Dielectric substratewith dielectric constant of 2.2 and 1.6mm thick. The dimensions of the microstrip patch antenna shown in Fig. 8are 36x20x1.6mm. The antenna bandwidth is around 5% for S11 lower than -9.5dB. However, the antenna bandwidth is around 10% for VSWR better than 3:1. The antenna beam width is around 72º. The antenna gain is around 7.8dBi. The directivity of the antenna is 8. The antenna gain is 6.03. The antenna efficiency is 77.25%. The computed S11 parameters are presented in Figure 9:

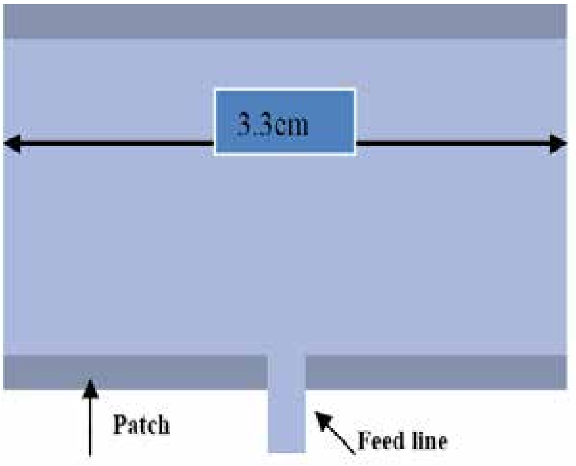


Figure 1: A microstrip stacked patch antenna

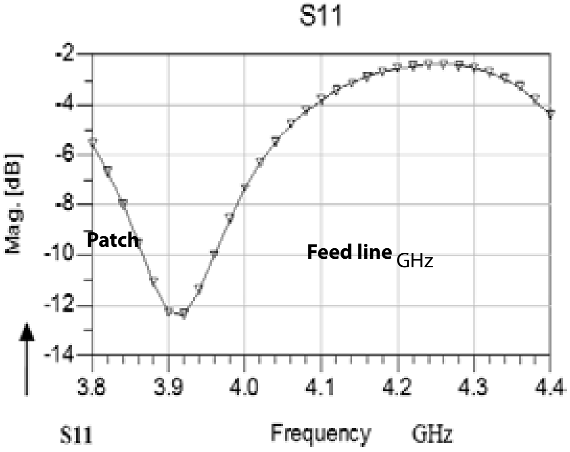


Figure 2: Computed S11 of the microstrip stacked patch

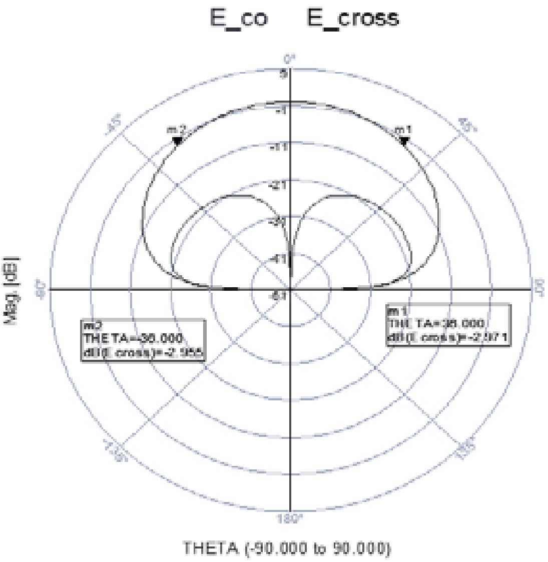


Figure 3: Radiation patternof the microstrip stacked patch

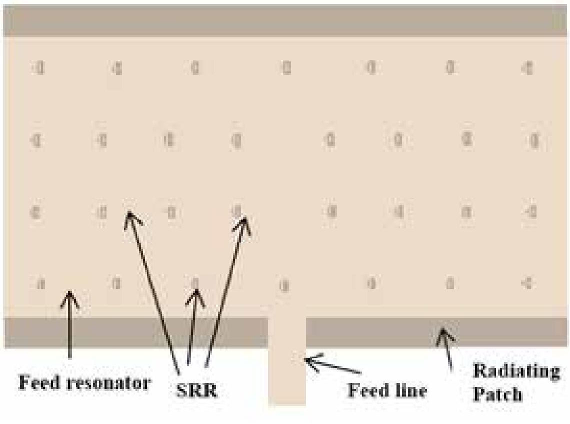


Figure 4: Printed antenna with Split Ring Resonators

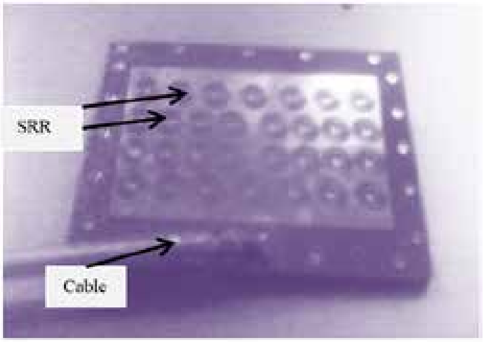


Figure 5: Meta-material patch Antenna with SRR

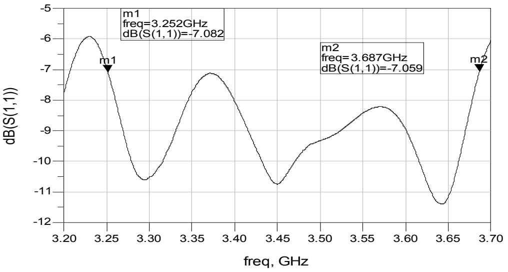


Figure 6 : Patch with Split Ring Resonators, measured S11

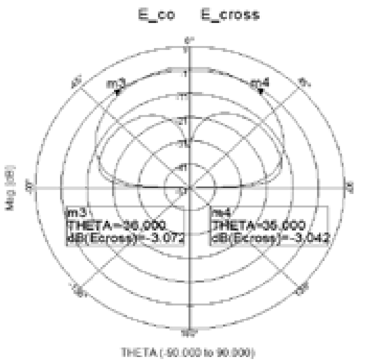


Figure 7: Radiation pattern for patch with SRR

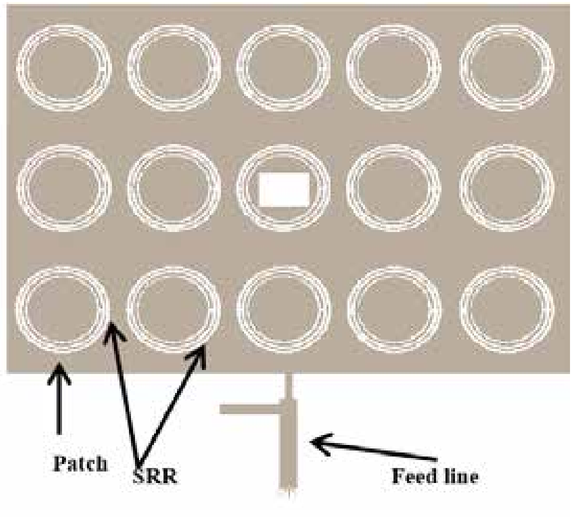


Figure 8 : Patch antenna with Split Ring Resonators

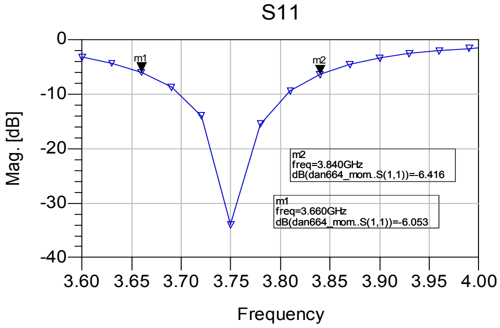


Figure 9 : Patch with Split Ring Resonators, computed S11

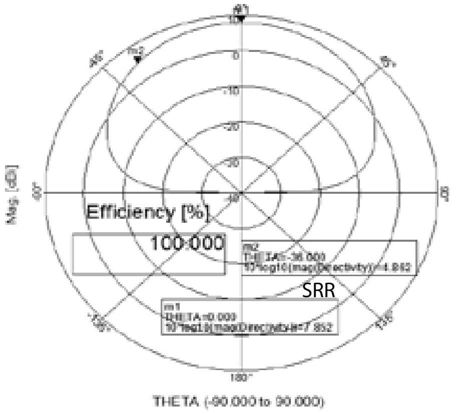


Figure 10 : Radiation pattern for patch with SRR

WIDEBAND STACKED PATCH WITH SRR

A wideband meta-materialstacked patch antenna with air spacing [1-4] has been designed. The antenna has been designed withSRR. The matching network and feed-lines are printed onFR4 dielectric substrate with dielectric constant of 4and 1.6mmthick. The radiating patch is printed on RT DUROID 5880 dielectric substratewith dielectric constant of 2.2and 1.6mm thick. The layers are separated by air spacing.The dimensions of the microstrip stacked patch antenna shown in Figure 11 are 33x20x3.2mm. The antenna has been designed and optimized by using Agilent momentum software. The antenna bandwidth is around 10% for S11 lower than -9.5dB. The computed S11 parametersare presented in Figure12. The computed results in Fig. 12 fit to the measured results. Radiation pattern of the stacked patch is shown in Fig. 13.The bean-width of the new stacked patch is around 72°. The antenna gain is around 9dBi. The antenna efficiency is 95%.

METAMATERIAL WEARABLE ANTENNAS

The proposed wearable meta-materials antennas may be attached to the patient as shown in Fig. 14a and Fig. 14b.

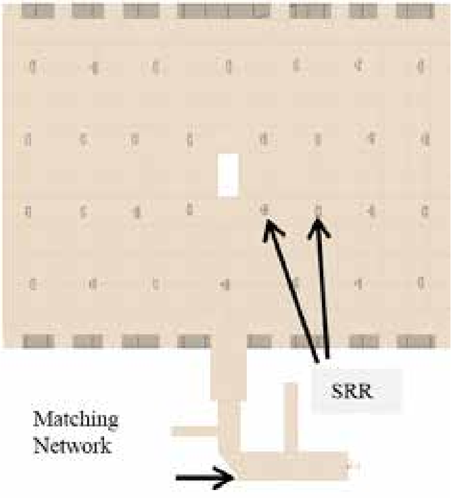


Figure11: Wideband Stacked Patchantenna with SRR

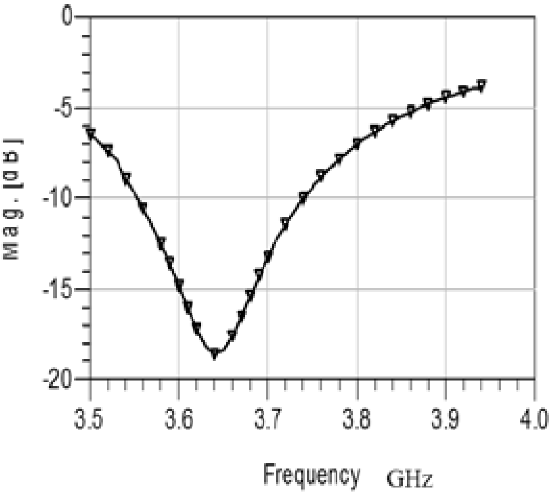


Figure12: S11 of the Wideband Stacked antenna with SRR

The antennas electrical performance on human body has been measured on a phantom. The phantom represents the human body electrical properties as presented in [2].

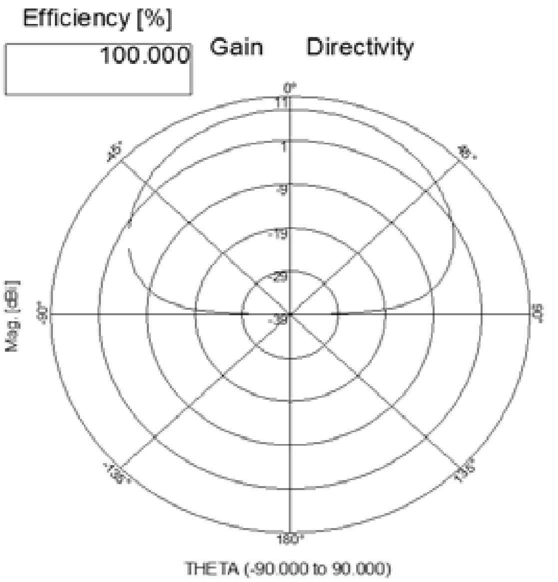
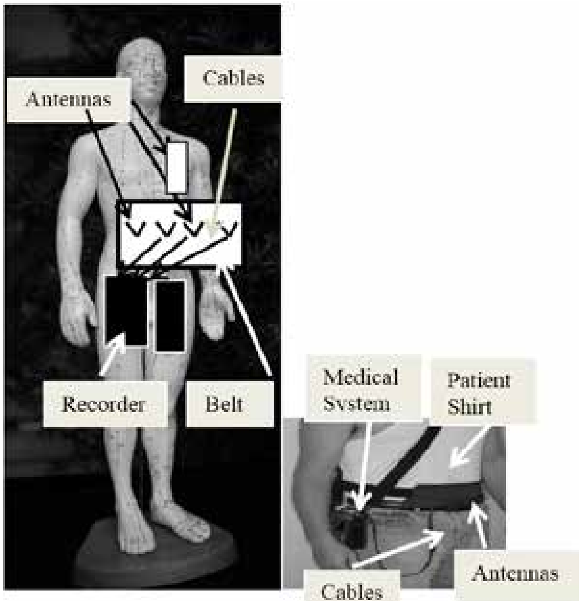


Figure13: Wideband antenna with SRR,Radiation pattern



a **b**

Figure14: Medical system with printed Wearable antenna

During S parameter and radiation pattern measurements the antennas were connected to the phantom. More antennas may be attached to the patient bodyat different locations to improve the level of the received signal. The cable from each antenna is connected to the medical system. The received signal is transferred via a SPNT switch to the receiver. N represents the number of the receiving antenna connected to the medical system.The medical system compares the received signals and selects the signal with the highest power. When analyzing wearable antennas in the near-field zone thereceiving and transmitting antennas are magnetically coupled. In Fig. 15 photos of meta-material antennas with SRR are shown.

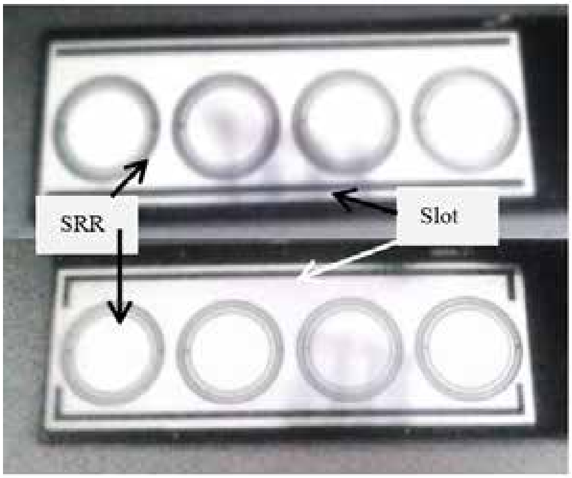


Figure 15: Meta-material antennas for medical applications

NEW ANTENNAS WITH SPLIT RING RESONATORS

A microstrip dipole antenna with Split Ring Resonators, SRR, is shown in Fig. 16. The microstrip loaded dipole antenna with SRR provides horizontal polarization. The slot antenna has vertical polarization. The resonant frequency of the antenna with SRR is 400MHz. The resonant frequency of the antenna without SRR is 10% higher. The antennas shown in Fig. 16 consist of two layers. The dipole feed line and matching stubs are printed on the first layer. The radiating dipole with SRR is electromagnetic coupled to the feed network. The thickness of each layer is 0.8mm. The antenna structure generates a dual polarized antenna. The computed S11 parameters are presentedin Fig. 17 The length of the antenna with SRR shown in Fig. 16 is19.8cm. The length of the antenna without SRR, as presented in [2], is21cm. The ring width is 1.4mm the spacing between the rings is 1.4mm. The antennas have been developed and optimized by using ADS software. The matching stubs locations and dimensions have been optimized to match the antenna to 50Ω. The length of the stub S in Fig 16 is 10mm. The antenna axial ratio may be varied from 0dB to 30dB by optimizing the locations and number of the coupling stubs.The number of coupling stubs may be optimized to yield the desired antenna characteristics. The number of coupling stubsin Fig 16 is three. The antenna axial ratio value may be

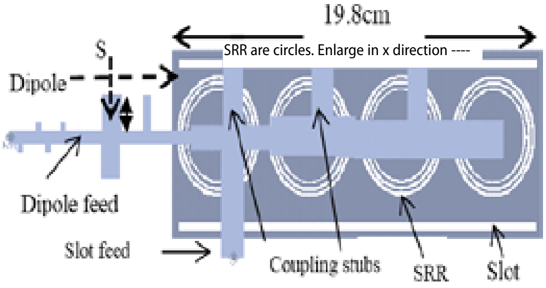


Figure 16: Printed antenna with Split Ring Resonators adjusted also by varying the slot feed location.

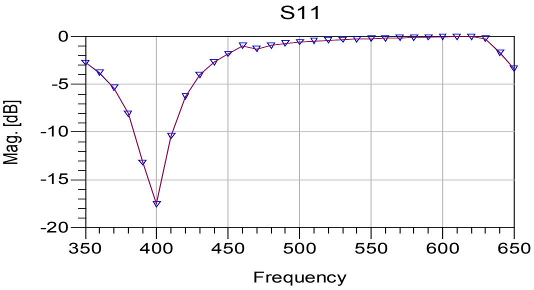


Figure 17 : Antenna with SRR computed S11

Metallic strips have been added to the antenna with SRR as presented in Fig. 18. The antenna bandwidth is around 50% for VSWR better than 3:1 as presented in Fig. 19.

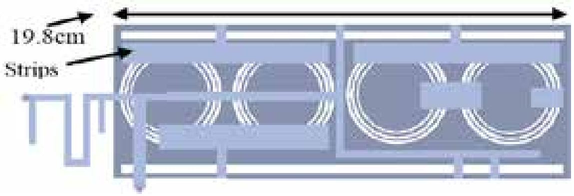


Figure 18: Antenna with SRR and Metallic strips

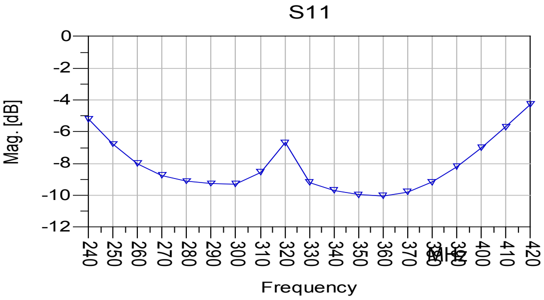


Figure 19: S11 for antenna with SRR and metallic strips

CONCLUSION

Meta material technology is used to develop small antennas with high efficiency. A new class of printed meta-materials antennas with high efficiency is presented in this paper.Three types of antenna was presented patch antennas with SRR, stacked patch with SRR, dual polarized printed dipole antennas with SRR. The bandwidth of the antenna with SRR and metallic strips is around 50% for S11 lower than -7.5dB. Optimization of the antenna feed network may be used to tune the antenna electrical characteristics and number of resonant frequencies. The length of the antennas with SRR is smaller by 5% to 10% than the antennas without SRR. Moreover, the resonant frequencyof the antennas with SRR is lower by 5% to 10%than the antennas without SRR. The gain and directivity of the patch antenna with SRR is higher by 2 to 3dB than the patch antenna without SRR.The resonant frequency of the new antenna with SRR on the patient under medical test is shifted by 3%.

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