

A New Type of Reconfigurable Antenna for Multi-band Wireless Communication

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Abstract

We propose a new reconfigurable multi-band antenna. The antenna consists of one feeding line as monopole antenna and four U-shaped (half-ringed) resonators. Two of U-shaped resonators are paired and placed in opposite (end-to-end) to form a broken (ring) circle as a subset. In each subset the broken ends of U-shaped resonators are connected or disconnected to control the resonate characters. By different combination of connections, nine different resonating types can be created. The circuit was realized in PCB and results show nine resonating types under the condition of $VSWR=3:1$ and frequency $< 4\text{GHz}$, which can cover several standard wireless communication bands, including DCS(1710-1880MHz), PCS(1880-1990MHz), UMTS(1900-2170MHz), WiBro(2300-2390MHz), Bluetooth(2400-2480MHz) and 802.11b,g (2400-2497MHz)

Key words: multi-band, monopole antenna, resonators, PCB

I. Introduction

In recent years, the rapid development of wireless communication leads to multi-functional gadgets. For example, mobile devices only used to transmit and receive messages. But now, it turns out to be a high integrated device, including vocal transmission, multi-media and high speed data exchange. This situation leads to great demand for mobile devices that are capable of operating different kinds of communication standards [1]. Besides, a smaller, slimmer and slighter device is the main market trend. These two requirements are being to trigger research on the design of small and multi-band antenna. However, it creates some problems for antenna designers due to the basic relationship between antenna sizes and radiation efficiency, which may cause degradation of communication quality.

Some recent studies of tunable antennas focus on few parasitical solutions [2] [3] or introduce different operating frequency antennas to realize multi-band purpose [4]. Antennas, however, have inner induced resonance will have clear technical benefits. A reconfigurable circuit can reuse its entire structure at different operating frequency so the size of the antenna can be reduced [5] [6]. Motivated by this thought, we designed and developed an antenna with ability to support multiple wireless services.

II. Design Consideration

Figure1. depicts the layout of the proposed antenna. The structure incorporates a microstrip feeding line, two sets of “U” shape resonators symmetrical about feeding line and vertical, four switches linking these resonators, as illustrated. The antenna is built on a 1.6 mm thick FR4 printed circuit board ($\epsilon_r = 4.3$, $\tan\delta = 0.02$), with $38\mu\text{m}$ thick copper metallization. FR4 is low cost and allows ease of prototyping. The size of the proposed antenna is $26.5 \times 20.6 \text{ mm}^2$. The geometrical dimensions were obtained by designing the antenna structure with the aid of EM simulation tool, namely Ansoft HFSS V. 11. The microstrip line is designed based on 50 ohm characteristic impedance.

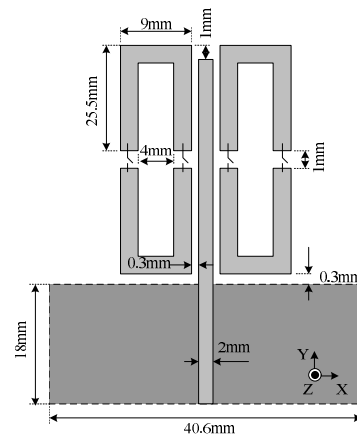


Fig. 1. Antenna structure

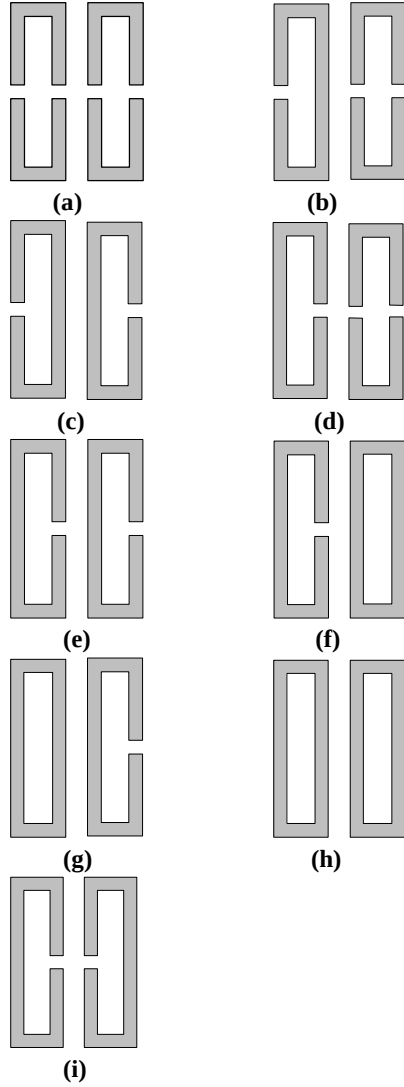


Fig. 2. Different types of antennas with direct connection or disconnection.

(a)FFFF, (b)FNFF, (c)FNNE, (d)NFFF, (e)NFNE, (f)NFNN, (g)NNNE, (h)NNNN, (i)NFFN

The four U-shaped resonators are excited by monopole antenna [7] which is the extension part of microstrip line. The structures of these resonators are reconfigurable by connecting each other by switches. If we defined “N” and “F” as short circuit and open circuit, respectively, nine usable types of antenna can be obtained as shown in Fig. 2. They are “FFFF”, “FNFF”, “FNNE”, “NFFF”, “NFNE”, “NFNN”, “NNNE”, “NNNN” and “NFFN”.

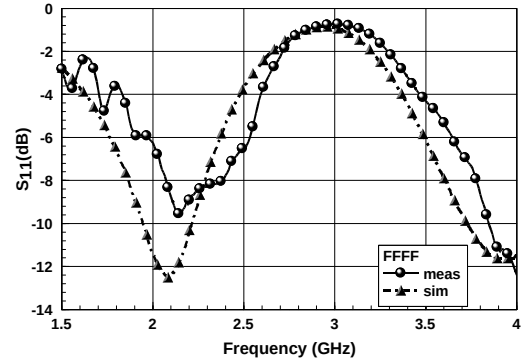
III. Results

A. Return loss

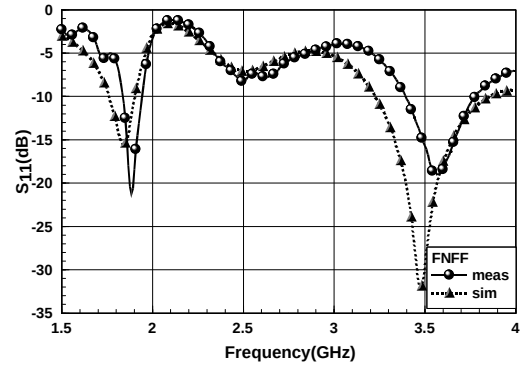
For the ease of analysis, the resonators are directly connected or disconnected. Nine different types of

configurations are behalf of ON and OFF states of switches as shown in Fig. 2.

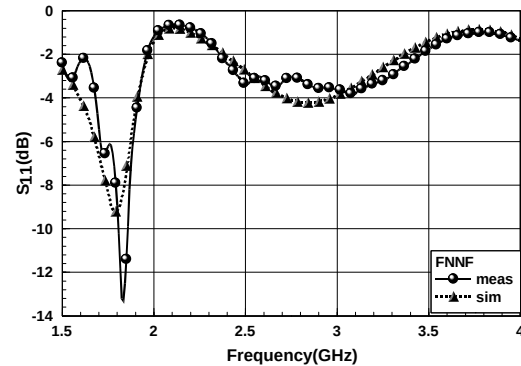
Agilent 8510C network analyzer is used to extract S-parameters and SOLT is the standard calibration procedure. Fig.3(a)-(i) show the measured return loss corresponding to the EM simulated ones. FFFF can cover the frequency range of DCS, PCS, UMTS and WiBro; FNFF can cover the frequency range of DCS; FNNE can cover the frequency range of DCS; NFFF can cover the frequency range of PCS, UMTS, Bluetooth and 802.11 b,g ; NFNN, NNNN and NFFN can cover the frequency range of WiBro, Bluetooth, 802.11 b,g, and WiMAX; NNNF can cover the frequency range of PCS.



(a)



(b)



(c)

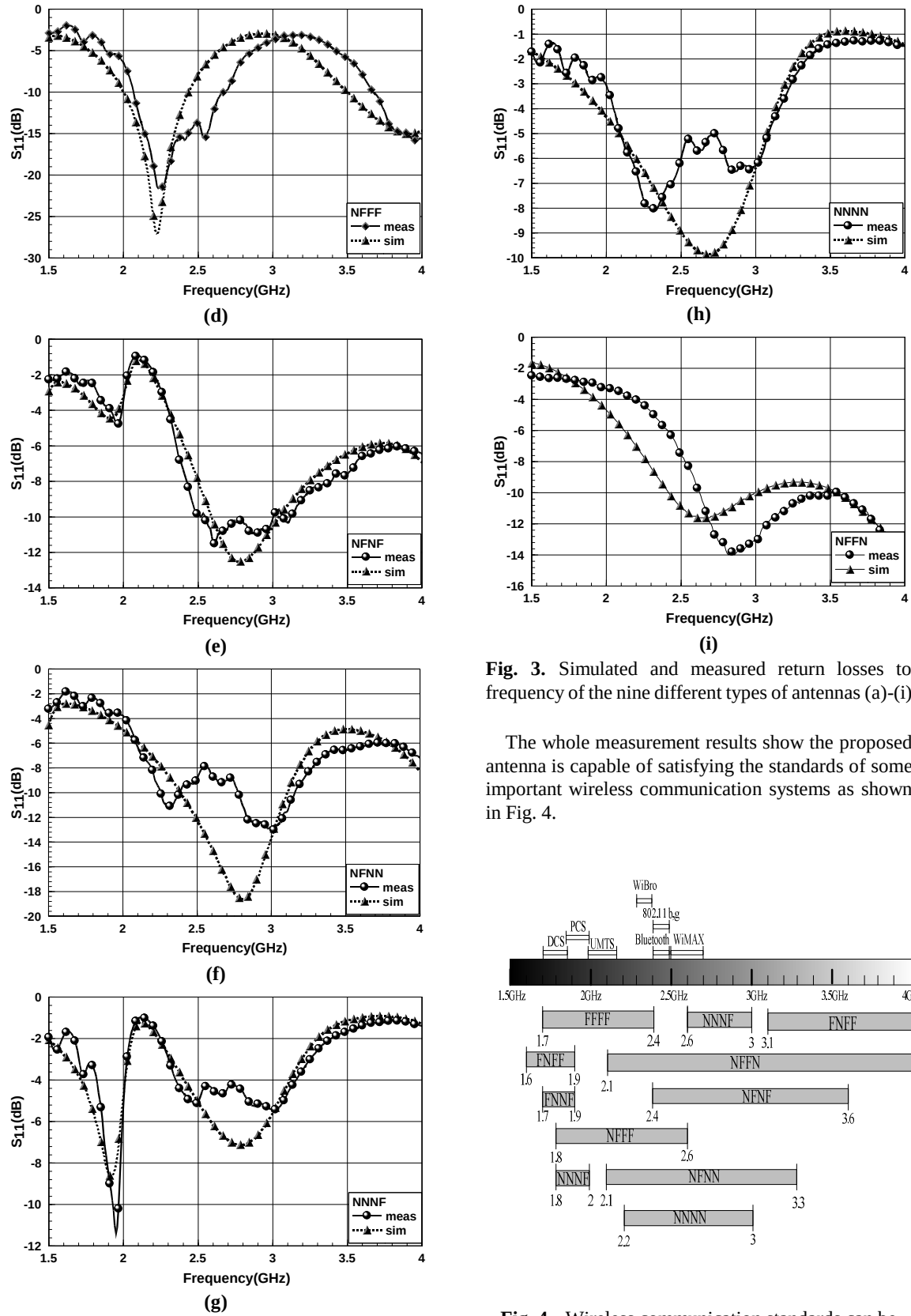


Fig. 3. Simulated and measured return losses to frequency of the nine different types of antennas (a)-(i)

The whole measurement results show the proposed antenna is capable of satisfying the standards of some important wireless communication systems as shown in Fig. 4.

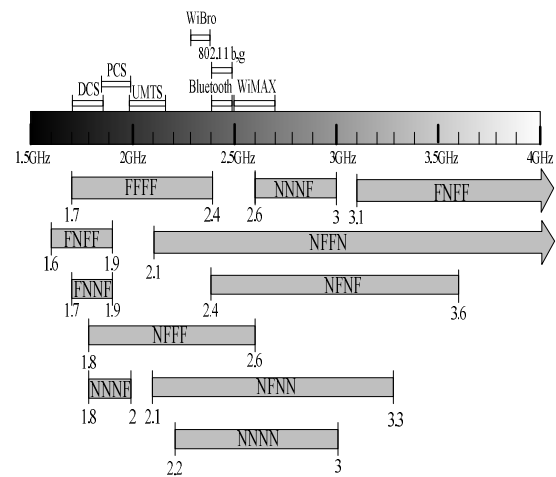


Fig. 4. Wireless communication standards can be covered in this proposed antenna

B. Current Distribution

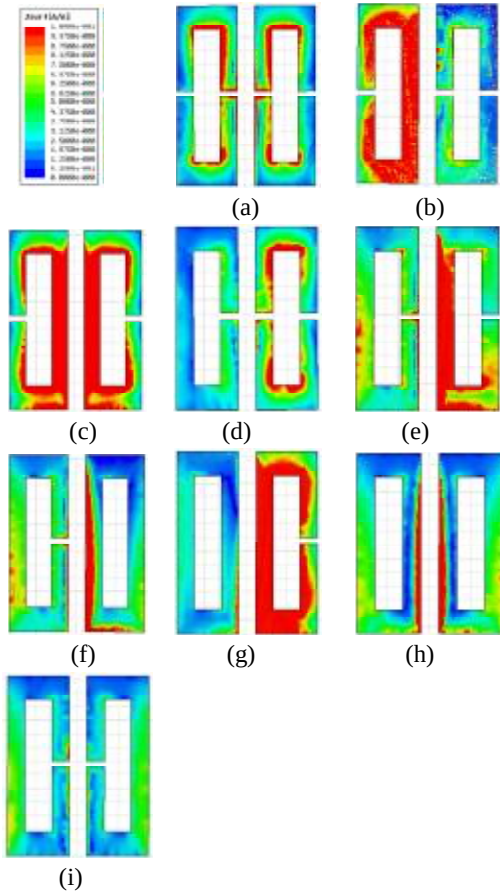


Fig. 5. Current distribution (a)FFFF (2080MHz), (b)FNFF(1840MHz),(c)FNFF(1790MHz), (d)NFFF(2200MHz),(e)NFNF(2780MHz), (f)NFNN(2800MHz),(g)NNNF(1900MHz), (h)NNNN(2680MHz),(i)NFFN(2650MHz)

It is well known that the resonance occurs at the half wavelength structure. For the ease of discussion, we considered the effect of main resonators except for the feeding line. Fig. 5. shows that not all resonators are strongly excited. It depends on the position between each resonator and the mutual coupling. In (b), (c), (e) and (g), there is at least one resonator which is connected in the side near the feeding line and disconnected in another. They excite the resonance frequency at about 1800MHz. In (a) and (d), the U-shaped resonators symmetrical about horizon are strongly excited. The total resonating length is somewhat less than (c). Therefore, it excites a resonance frequency at about 2200MHz. In (e), (f), (h) and (i), the vertical length is half wavelength and are excited at about 2700MHz.

C. Radiation Efficiency

Fig. 6. shows the entire radiation efficiency of nine configurations. It should be noted that besides the internal losses of antenna structure, entire radiation efficiency also take matching losses at the input port into account. The entire radiation efficiency is defined as

$$h_t = h_r (1 - |\Gamma|^2)$$

Where h_r is the antenna radiation efficiency, and Γ is the reflection coefficient. In each operating frequency range, entire radiation efficiency can reach over 70%.

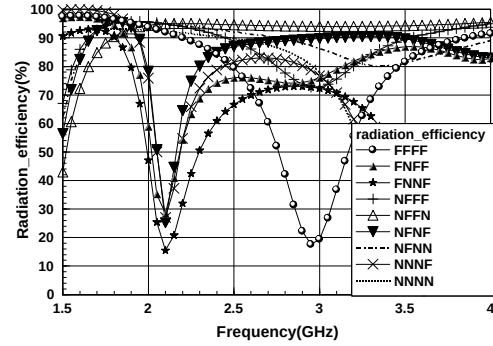


Fig. 6. Nine different types entire radiation efficiency

D. Radiation Pattern

In every interesting frequency range of nine types, H-plane(X-Z plane) radiation pattern is almost omni-directional while E-plane(Y-Z plane) radiation pattern is dumbbell-shaped as the figures from Fig.7-1 to Fig.7-11.

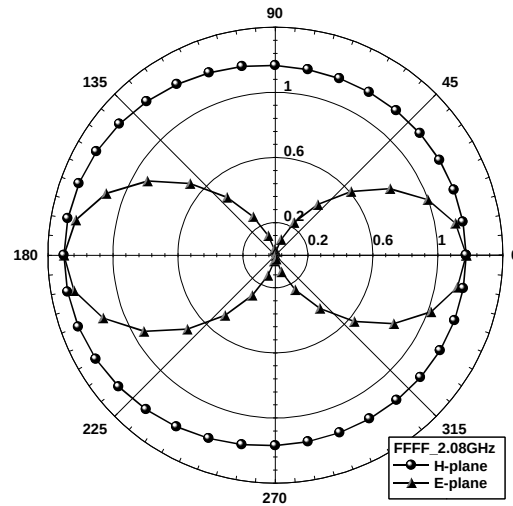


Fig. 7-1 FFFF radiation pattern at 2.08GHz

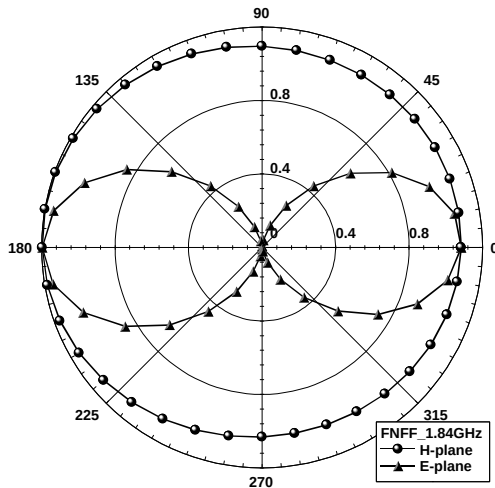


Fig. 7-2 FNFF radiation pattern at 1.84GHz

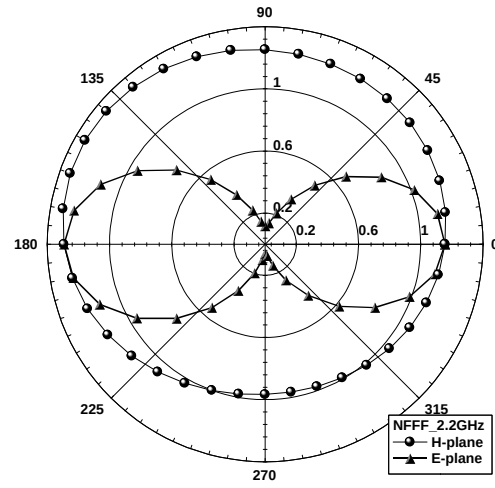


Fig. 7-5 NFFF radiation pattern at 2.2GHz

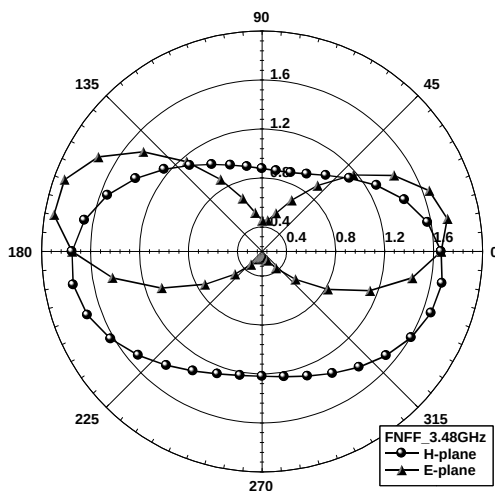


Fig. 7-3 FNFF radiation pattern at 3.48GHz

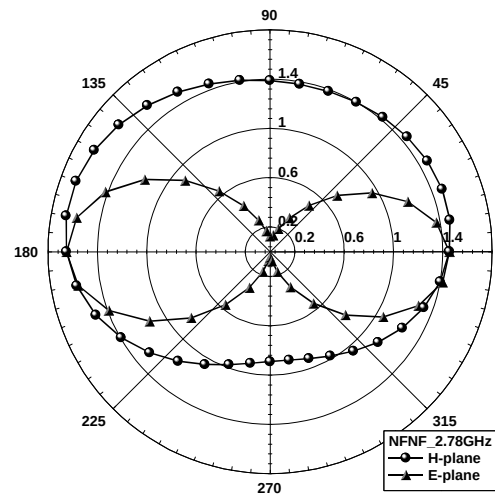


Fig. 7-6 NFNF radiation pattern at 2.78GHz

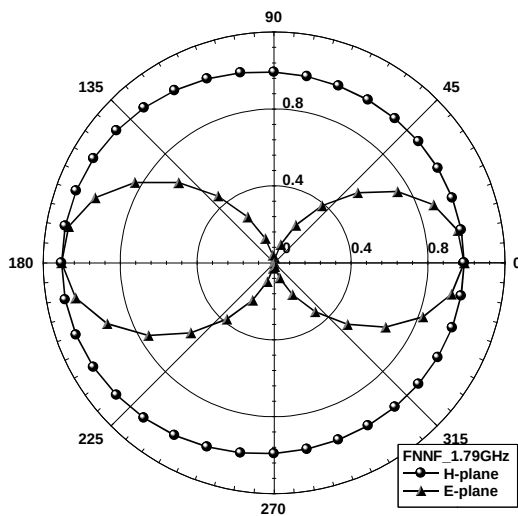


Fig. 7-4 FNNF radiation pattern at 1.79GHz

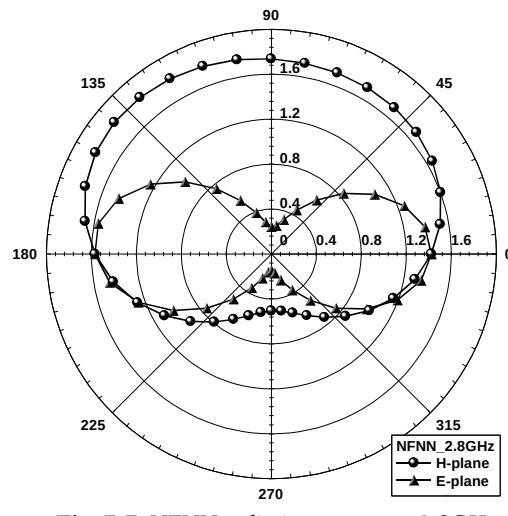


Fig. 7-7 NFNN radiation pattern at 2.8GHz

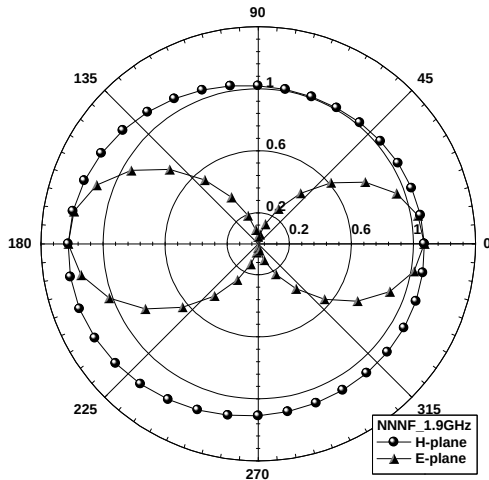


Fig. 7-8 NNNF radiation pattern at 1.9GHz

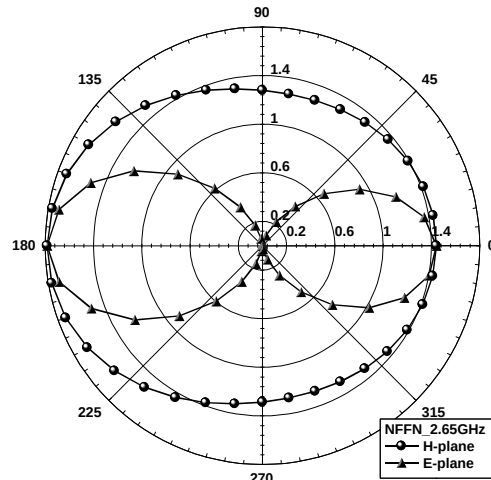


Fig. 7-11 NFFN radiation pattern at 2.65GHz

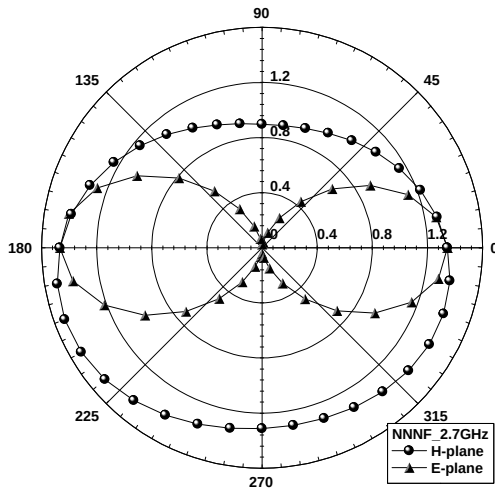


Fig. 7-9 NNNF radiation pattern at 2.7GHz

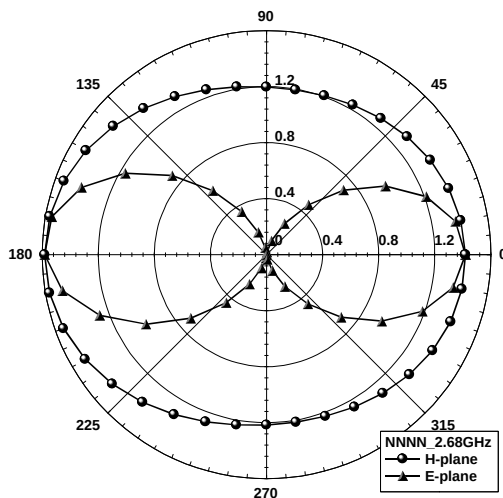


Fig. 7-10 NNNN radiation pattern at 2.68GHz

IV. Conclusions

A new technique for designing multi-band antenna is proposed. Measurement results show that this technique can cover some important wireless communication standards, including DCS, PCS, UMTS, Bluetooth, WiBro, 802.11 b,g and WiMAX. Radiation patterns are omni-directional in vertical plane suitable to the variation of environment. The reconfigurable resonators, though, are realized by direct or indirect connection, PIN diode or other switches will be utilized in the future.

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