Highly Effective Handset Antenna

M. Bank, M. Haridim, V. Tsingouz, Z. Ibragimov

Abstract - It is shown that the MB antenna, which uses the handset PCB as the radiating element, is equivalent to a full-wave dipole, i.e. each arm is half-wavelength long. This enhanced length of the dipole, and hence its improved properties, is achieved due to the fact that in the MB antenna the radiating arms are short-circuited at their ends. This approach allows increasing the antenna's gain by 3dB, as compared to the conventional dipole, while removing the need for a separate antenna to be installed on the PCB.

Keywords—Cell phone antenna, MB antenna, dipole

1. Introduction

THE unavoidable presence of a PCB (printed circuit board) in mobile phones often results in degradation of the phone's antenna performance, especially in terms of its efficiency and gain. Modern cellular phone handset antennas must comply with challenging requirements such as small size, and immunity to the influence the user's body. These requirements have led to development of different types of antennas, such as the planar inverted F antenna (PIFA) [1]. Dipole and monopole antennas, on the other hand, do not meet these requirements, because the presence of the PCB (acting as a ground plate at the cellular frequencies) degrades their efficiency. The advantages of the monopole antenna are omnidirectional pattern in the horizontal plane, easy design procedure and light weight. However, monopole as an internal antenna in compact cellular handsets is excluded, even though for a long time it has been the preferable choice in cellular phones.

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Recently, the so-called MB antenna has been proposed, which uses the phone's PCB as the radiating element such that there is no need for a separate antenna in the phone [2]. In this paper we show that the MB antenna is equivalent to a full-wave dipole with increased gain and efficiency, which allows to implement small handsets without antenna.

II. Long line, dipole, MB antenna

An open transmission long line comprised of two parallel wires is a standing waves system. Essentially, this system does not radiate electromagnetic waves, since the fields of the two wires cancel each other, as depicted in Fig. 1 [3]. However, folding the wires outward in opposite directions creates a dipole antenna and results in collinear currents along the arms of the dipole, such that the system radiates efficiently (see Fig. 1).

The reflection coefficient at the load μ_L, under open circuit conditions is [2]

$$\mu_L = \frac{\omega - \rho}{\omega + \rho} = +1,$$

where ρ is the line's characteristic resistance.

The current in at the line end is [2]

$$I\_L=(1-\mu\_L)Ix=0$$

So this line has zero current at its end (see Fig. 2) [4].

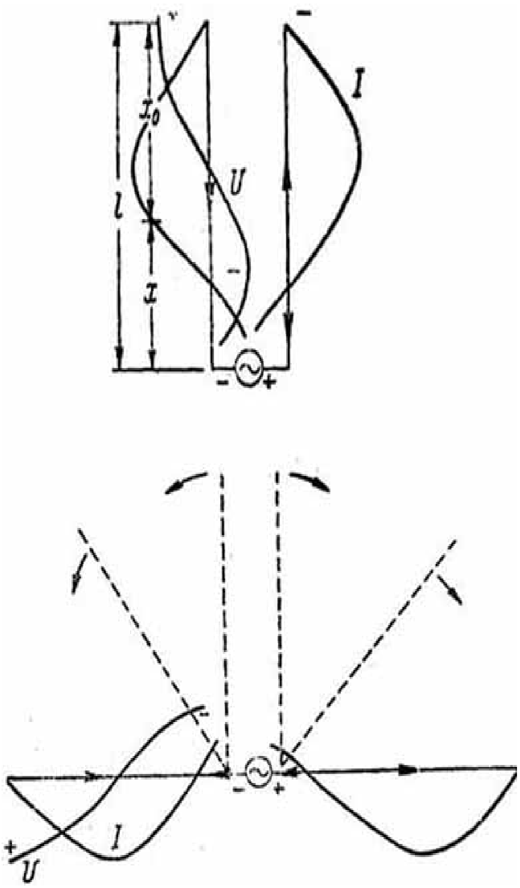

Fig. 1 From open two-wire line to dipole

The reflection from load coefficient μ_L will be [2]

[4]

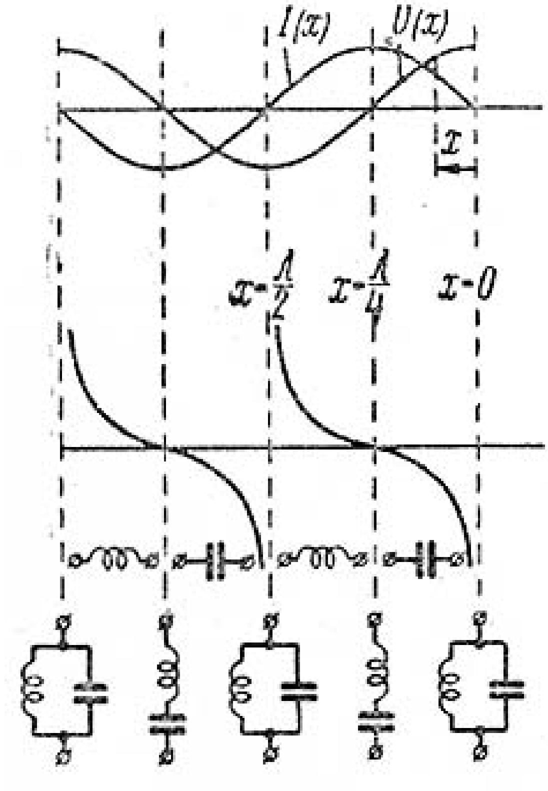

Fig. 2 Currents and voltages in open long line

The small current near the open end of a line (vanishing at the line end) decreases the efficiency of "open" antennas, such as dipole, monopole, and PIFA.

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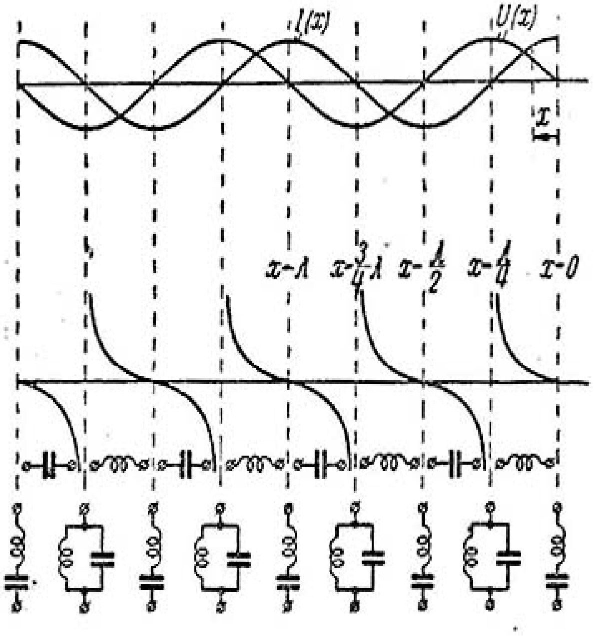


Figure 3- current and voltage profile along a shorted transmission line

High currents at the line end can be achieved in the case that the line is short-circuited at its end. In this case with $\rho \to 0$, we have (see Fig.3):

$$\mu_L = \frac{\omega - \rho}{\omega + \rho} = -1,$$

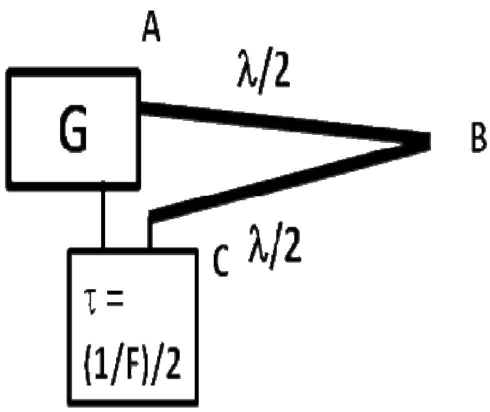
$$I_L = (1 - \mu_L) Ix = 2I_x = I_{max}$$

Therefore, the efficiency of a dipole and/or monopole can be increased if one can create a short-circuit at the end of these antennas. This feature is realized in the MB antenna [2].

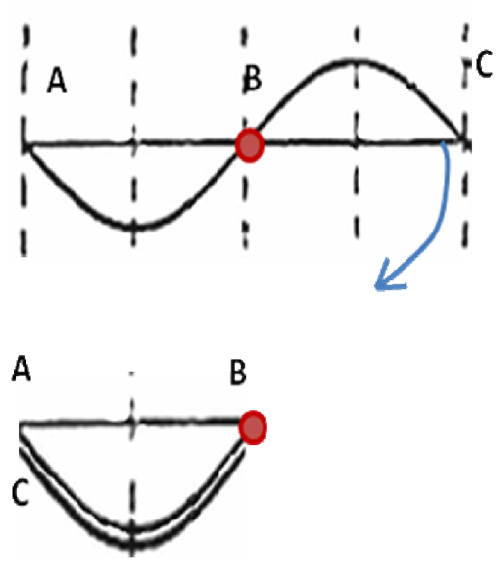
The feeding scheme of the MB antenna is based on the principle of the One-Wire line system (B-Line) described in[5].

We'll first describe the basic idea behind the B-line. In the case of a regular line the wires are both directly connected to the generator, and the currents in the two wires flow at opposite directions. In the B-line, the current in one of the line wires is inverted by means of a 180 degree phase shifter (an inverter) so that the wires currents have the same polarity. Consequently, one can combine the two wires leading to a single-wire line. The loading scheme of the B-line is described in [5].

In the case of the MB antenna, an inverter (180^0 phase shifter) is inserted between the generator and the feed point of the antenna, and the two radiating arms of the antenna are connected together at their ends, as depicted in Fig 4a. The arm lengths are half wavelength. As it can be seen from Fig. 4b, at point B, the current phase and direction are inverted simultaneously, and consequently the currents in the two arms are identical. The delay line is designed such as to provide an optimal connection between the generator and the wires.



(a)



(b)

Fig. 4 From a shorted two-wire line to MB antenna

Now, it is possible to combine the two arms of the dipole into a single radiating element, e.g. the mobile handset's PCB as a radiator of height λ/2. This antenna, called the MB antenna, is equivalent to a full wave (λ/2 × 2) dipole. A further unique characteristic of this antenna is that since the open circuit condition at the arm ends is avoided, the current at the end of the radiating element is not zero, and hence the antenna efficiency is significantly increased. These properties of the MB antenna are verified by CST simulations shown below. Another important feature of the MBA is related to its radiation resistance (Rrad). It is known, that a dipole with a total length of 0.5λ would have Rrad ≈ 100 Ω. However, since some parts of this dipole do not radiate, its radiation resistance is decreased to Rrad to ≈ 75 Ω.

The transition from a dipole antenna to the MBA is actually a transition from parallel connection of the dipole arms in the conventional dipole to a series connection of the radiating elements in MB (Fig. 4). As a result, the radiation resistance should be reduced by four times. Therefore, we can expect that the MBA's radiation resistance is approximately 15-30Ω, which depends on PCB dimensions too. Changing the antenna radiation resistance should not influence the overall link budget calculations of a cellular system, in which the same antenna is used for transmitting and receiving of data. However, a smaller antenna resistance may reduce the noise level at the receiver input. Obviously, this rather intuitive estimation needs to be verified by simulations and measurements.

III. Simulations

As stated in Section 1, the MB's delay line must be very compact and lossless for implementation in modern cellular handsets. In our simulations, we used a two-pole line hereinafter- One Way Strip-Line or OWSL)which consists of a thin conducting (e.g. copper) strip formed on the top of a high permittivity dielectric substrate separating the strip from a conductive layer (not grounded) on the bottom surface of the substrate.(

In this Section we present the simulation results for a dipole and an MBA both designed for a center frequency of 2.14 GHz. Fig. 5 shows the dimensions and simulation results for S11 parameter of the dipole.

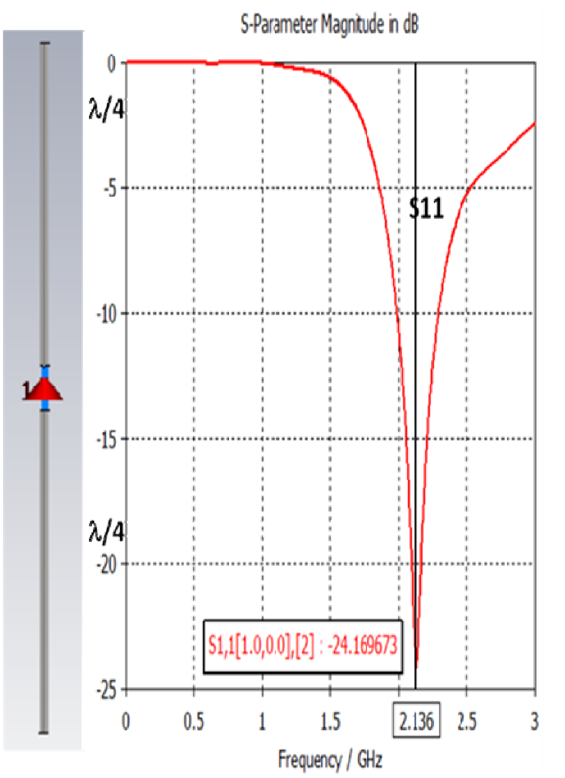


Fig. 5 dimensions and S11 parameter of the dipole (simulation), reference impedance 73 Ohms, amplitude 1V

Fig. 6 shows the simulation results for the far field and gain of the dipole. As shown in Fig.6, the receiving gain is 2.17 dB. i.e. the dipole theoretical gain [6]

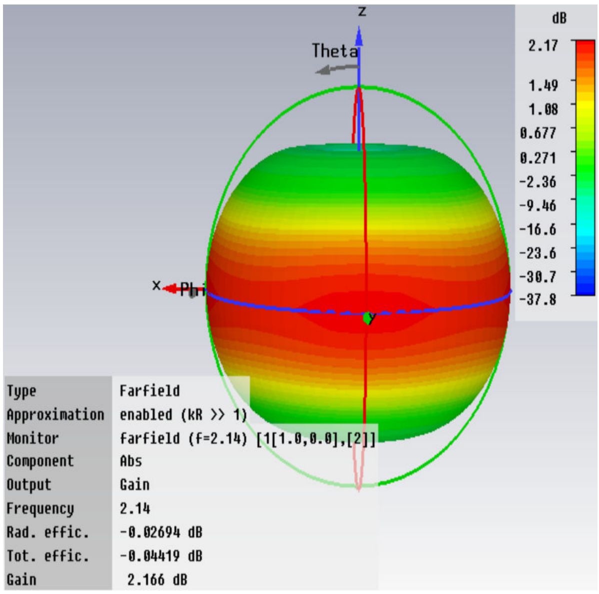


Figure 6- Gain of the dipole of Fig. 5 (simulations)

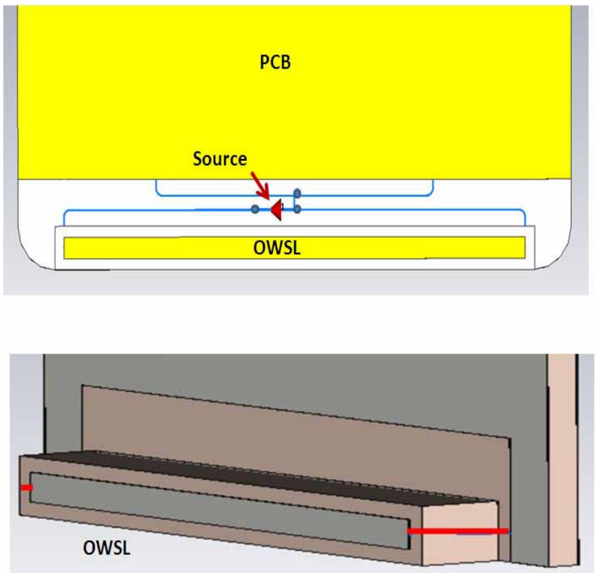


Figure 7- The MBA model in CST simulations

Fig. 7 shows the simulation model of the MBA designed for the same center frequency as the dipole. Here, the radiating element is a handset PCB and the delay line is implemented as OWSL. The simulation results for MB's S11 and radiation resistance are shown in Fig. 8.

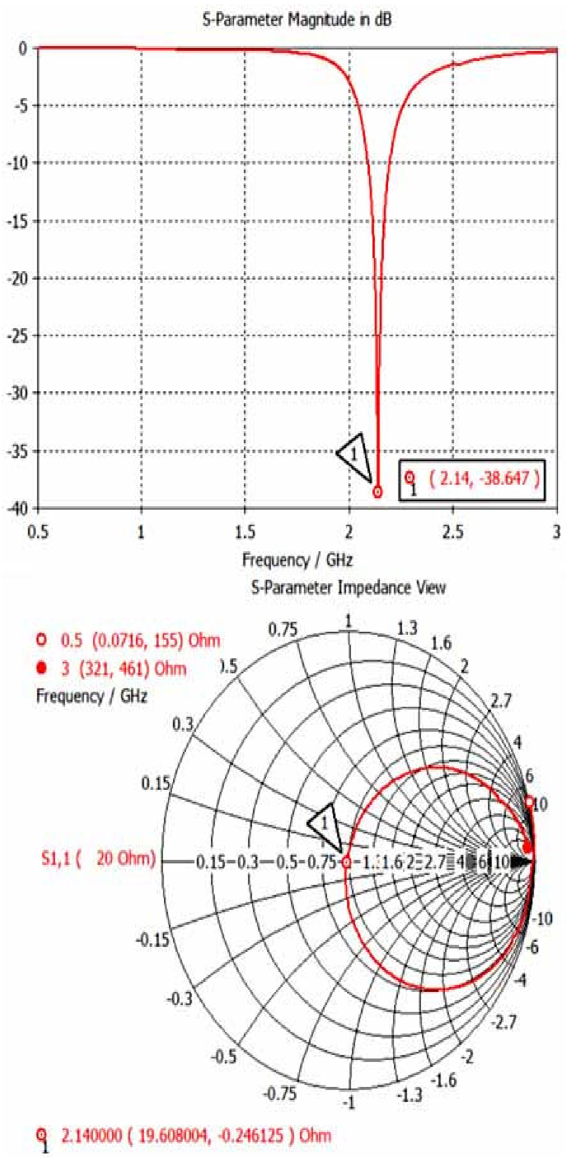


Figure 8- Simulation results for S11 and radiation resistance of MB (20 Ohm)

Fig. 9 shows the simulation results for the far field and the gain of the MBA of Fig. 7.

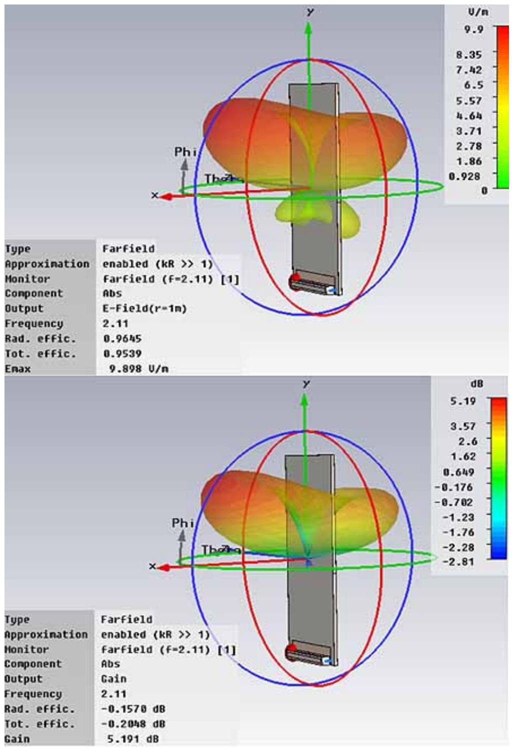


Figure 9- Far field (at 1 m) and gain of the MBA (simulations)

The presented results clearly show that the MBA has superior performances over the dipole in all important parameters. In particular, the MB's gain is higher that the dipole gain by 3dB. It is worth noting two features of the MB antenna.

Firstly, the electrical length of the delay line in the MBA is half wavelength, and it is connected between the leads of the signal source. Therefore, there is no current in the delay line, because the potentials at its ends are the same.

However, for the second harmonic of the signal, (if present at the generator) the electrical length of the delay line is equal to full wavelength, and hence it shorts out the generator output, resulting in a high current in the generator-delay line loop. This means that for the second harmonic, the delay line radiates rather than the PCB. The results of simulations for this case are shown in Fig.10

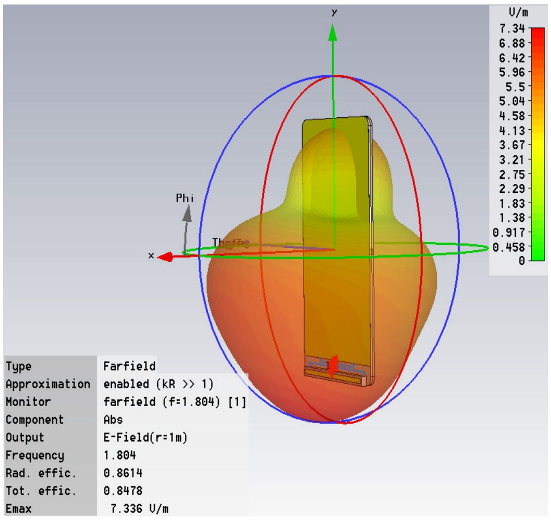


Figure 10- Far field (at 1 m) of the MB antenna when the delay line corresponds to one wavelength

Secondly, in order to evaluate the antenna's performance, besides the antenna's maximum field strength and gain, one should consider also its radiation pattern Even in the case of a high gain and field strength, the radiation pattern may be irregular in the horizontal plane, which can seriously degrade the cell phone performances. We can expect that the MB antenna may be advantageous also in this aspect, as its radiation pattern is completely symmetric.

about it's in contrast to the widely used PIFA, which mounted on one side of the PCB. Fig.'s 11 and 12 show the radiation patterns of PIFA [7] and MBA at 2 GHz, respectively. This feature of the MBA is clearly confirmed by the simulation results presented in Fig.'s 9, 11, 12.

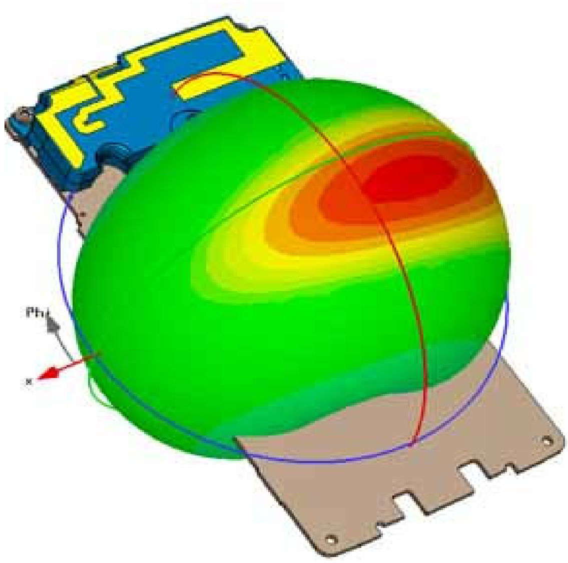


Fig. 11. The PIFA radiation pattern

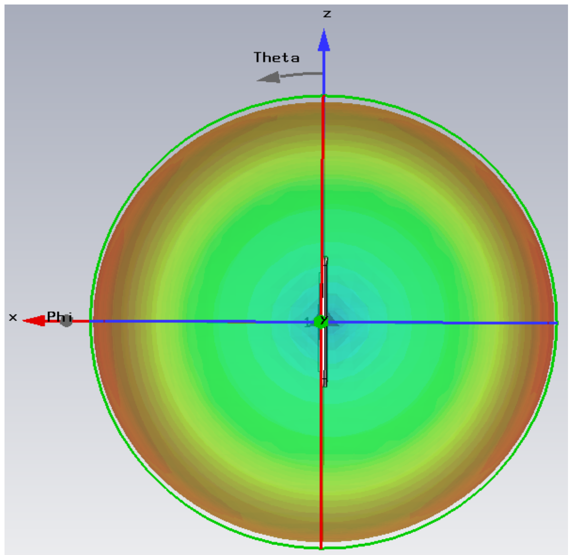


Fig. 12 MB antenna radiation pattern

IV. Conclusion

The operation principles of the MB antenna are described. It is shown that the MBA exhibit higher gain and efficiency, compared to a dipole. The enhanced performances of the MBA is attributed to the fact that the MBA is based on a shorted two-wire line approach, which is in contrast to the conventional linear antennas with open ended arms.

One important advantage of the MB antenna lies in the fact that its promising characteristics are achieved while removing the need for a separate antenna to be implanted in a mobile unit.

Another advantage of MB is its circular radiation pattern.

Improving the MB gain by 3 dB in the transmitting mode and by 3 dB in receiving mode allows doubling the communication range.

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