J- Antenna for 160, 15 and 10(FM) meters
Unusual Look to Usual Things

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Introduction

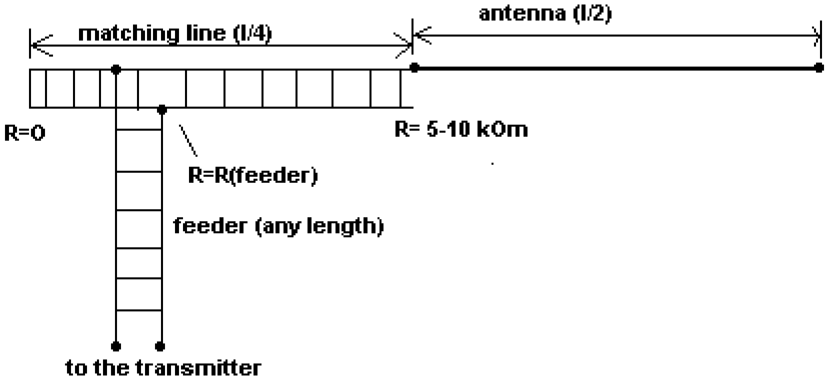
After getting my first amateur license I had to think, what antenna to build for a top-band (160 m), I realized, that conditions are too bad for it. I live in a 7-floor house, which has a roof with a high slope (about 35-40 degrees), which is very dangerous to operate on it. Also, the house is almost completely surrounded by wide streets and electrical wires going along them. After long thinking, I concluded, that there is only one possibility to make an antenna - to hang up a long wire from my roof to the roof of another house. Unfortunately, any dipole-type antenna was unacceptable, because in this case my apartment would have been too far away from the feed point of the antenna, and the condition of right angle (90^o) between feeder and antenna itself could not be satisfied. Fortunately, in that time I have read about one very old, but not frequently used antenna - so called Zeppelin-antenna with a matched feeding.

Classical design with an opened line

Actually, this is shortly described in well-known book ("Antennenbuch"), written by DM2ABK (Karl Rothammel), but has been recently developed by Sergey Makarkin (RX3AKT), a radioamateur from Moscow, who has published a good article in "Radio-Design" journal (N2, 1998).

Classical design is presented below (**Figure 1**). As it can be seen, there is feeder with rather high impedance (~300-600 Ohm), and 1/4-wavelength matching line. From one end, this line is shortened, and here its impedance is just a zero (current is high, but voltage is almost zero). Another end of this line is connected to the long wire, which has length exactly 1/2 wavelength. At this point, the impedance is very high (several kiloohms). That is why, a big voltage exists here during a transmission. This is quite suitable for a wire feeding, because a 1/2-wavelength has high impedance when fed from the end.

Figure 1. Classical Zeppelin-antenna design



The feeder from the transmitter with a specific impedance R_f is connected to the matching line in the point, where impedance of the latter is equal to that of the feeder. Such point is usually located not so far from the shortened end. If everything is done properly, feeder may have any length and SWR is closed to 1:1 in rather narrow band, central frequency of which is determined by the geometrical size of matching line and antenna.

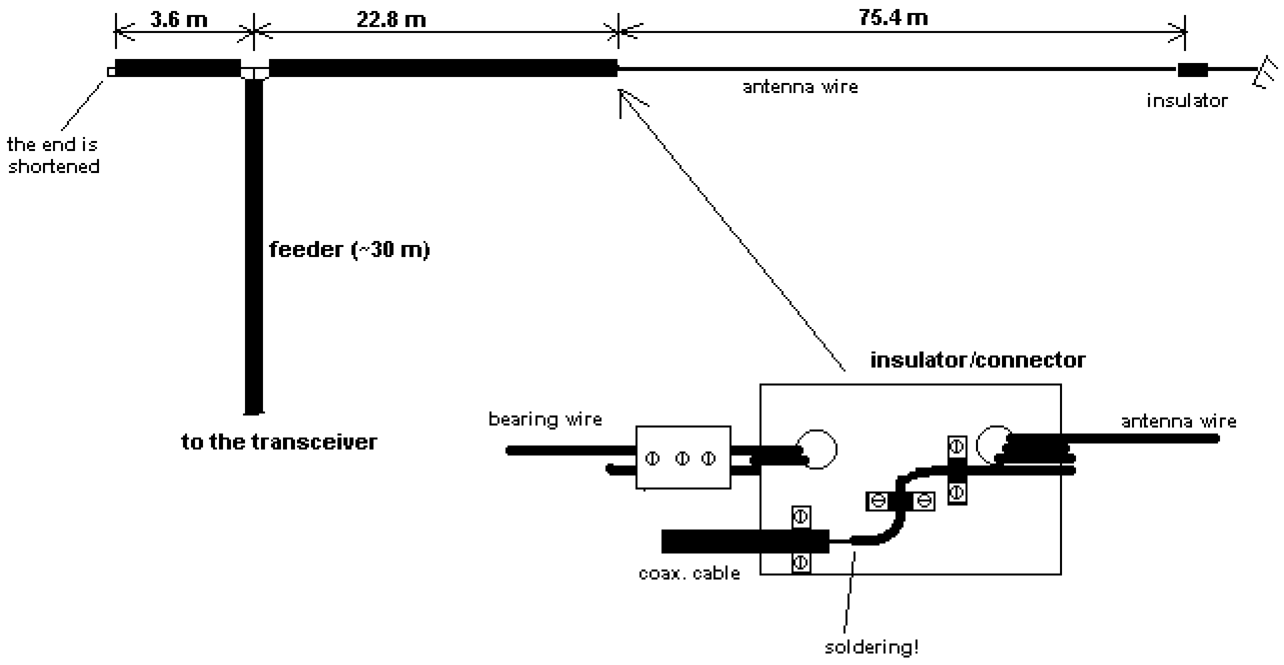
Classical design with a coaxial cable for 160 meters

This design can be used almost without change, but instead of symmetrical feeder a coaxial cable can be used to connect the whole system to the unsymmetrical output of the transmitter (**Figure 2**). Using of a coaxial cable instead of an open line has one big advantage – in contrast with the symmetrical transmission line it is almost insensitive to the environment, weather conditions and can be placed really everywhere.

Such antenna with feeding 'from the end' is much more easy to make, that a simple dipole. Here, antenna wire bears only itself, and this reduces the mechanical strength and thickness of the wire to be used. Also, you may use your window as one the point of antenna fixing. In this case, all the cable will be inside your shack and antenna could be tuned precisely in comfortable conditions. If the beginning of antenna is outside the apartment, most part of matching line can be used as the continuation of the feeding cable.

On **Figure 2** there is a design, that I implemented for using on 160 m amateur band, and which, to my mind, is a perfect solution for the people, who cannot mount a classical dipole.

Figure 2. Long wire antenna for 160 m with a coaxial matching line.



In my case, all coaxial cables have 75 Ohm impedance, the antenna wire, as well as two bearing wires are made from very hard bimetallic insulated cable (outer diameter is about 3 mm). The trickiest part - the connector between cable and antenna - is shown on **Figure 2**.. It should be noted, that voltage on it is quite high, and so everything should be well insulated from each other. It is good idea to place this connector somewhere indoors, otherwise rains and snow may cause decreasing of insulation efficiency and antenna performance. This antenna uses a tuned line made from the coaxial cable, and for proper operation of the whole system the antenna wire should have the length equal to the $\lambda*0.95/2$, and the coaxial line must resonate on the working frequency.

It is a good idea, to connect the shortened end of the matching line to the ground (cold water pipe, heating system, building elements etc.) to provide adequate safety and to reduce possible TV/RF interferences while transmitting.

Tuning and adjusting of the antenna

To achieve what was declared in the previous paragraph, first of all the precise length of the matching line should be determined. Theoretically, it should be closed to $\lambda/(4*sqrt(d))$ (sqrt - Square Root, d - dielectric constant of the insulator used in the coaxial cable). SQRT(d) value is typically about 1.52 for most cables with polyethylene-based dielectric, that is why, 'shortening coefficient' is about 0.66. But the practical value will be a little different from that.

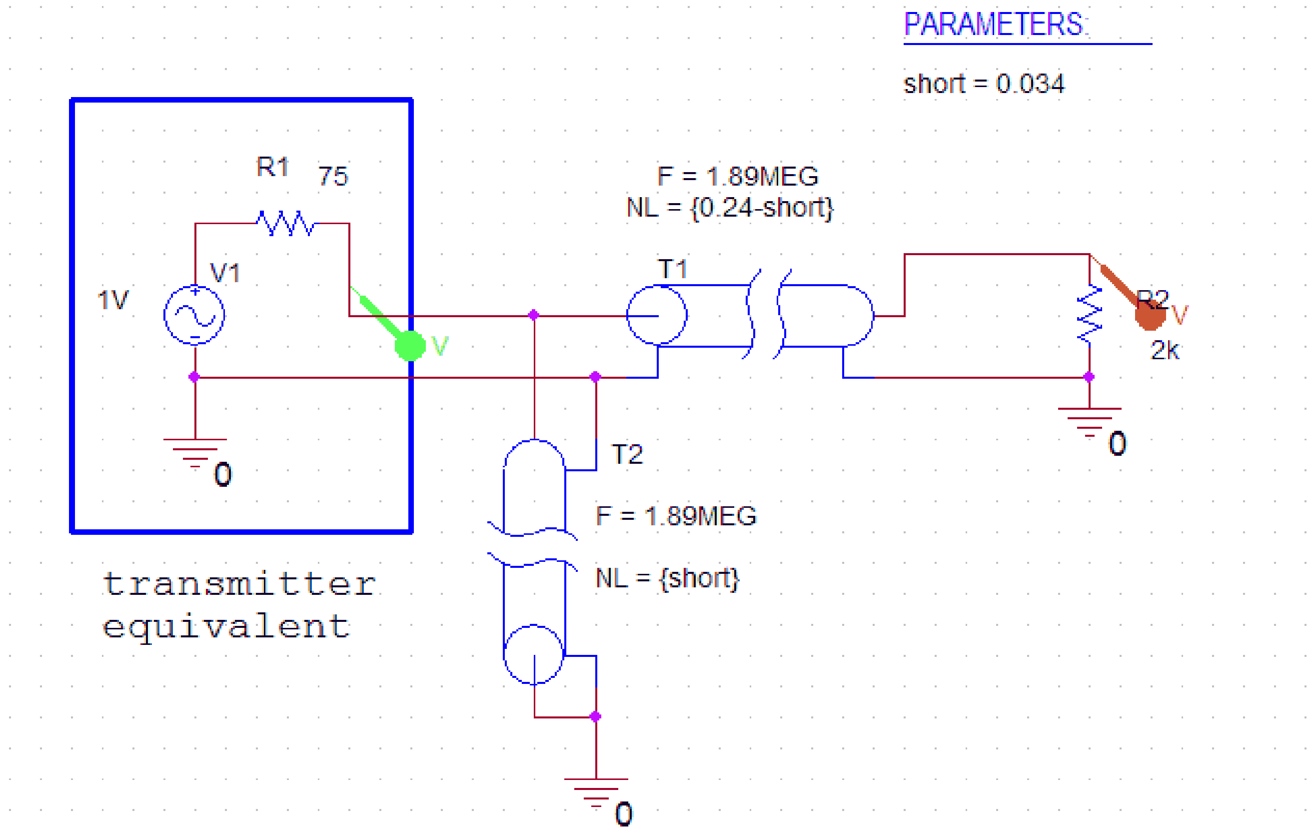
The lengths indicated on **Figure 2** are mine values, and they can be used as the approximate reference. Exact numbers depends on the antenna environment and should be determined experimentally. It should be noted, that in ‘ideal’ case it is not a simple task, because in such system three values have to be varied (one is antenna length, and another two are lengths of the parts of the matching line). But as it appeared from my experience, for practical purposes the most important thing is to choose correct total length of the matching line, which must resonate on the desired frequency.

To do this, I suggest to use the following technique. To make your line resonate on the middle of the band (1890 kHz), you first have to make the line about 1 m longer, that estimated length of the tuned line (for example, 24 m), making shortened segment about 3.6 m. Then, connect the 2-3 kiloohms resistor to the “open’ end of the line, and the transceiver through SWR meter - to the feeder. The resistor here serves as a loading instead of the antenna wire.

After assembling of the system, put RF power (1-2 W or even less is enough) on some frequency inside 160 m band into line and watch the SWR. If the line is completely out of resonance, SWR will be closed to infinity, and no power will be dissipated on the resistor. Then, the frequency should be found, which gives the sharp minimum of the SWR. It has to be around 1800 KHz. Here, the SWR is usually less than 1.5:1, and the full power of the transceiver is dissipated on the resistor, which means, that the matching line works well. When touching the 'hot' end of the loading, it may be seemed, that is really very hot – this is due to the high HF voltage, which causes skin burning (be careful to do it, even by low power of RF source!).

For better understanding of these processes is useful to look to the results of simulation of this system using Pspice simulation software. The equivalent schematics (**Figure 3**) includes voltage source V1 in series with 75 Ohm resistor (which emulates output resistance of the transmitter), two coaxial lines T1 and T2 and loading R2. Since Pspice does not allow to set lengths of the transmission lines directly in length units, they are set in wavelengths (NL) on the specified frequency (in our case, F=1.89 MHz).

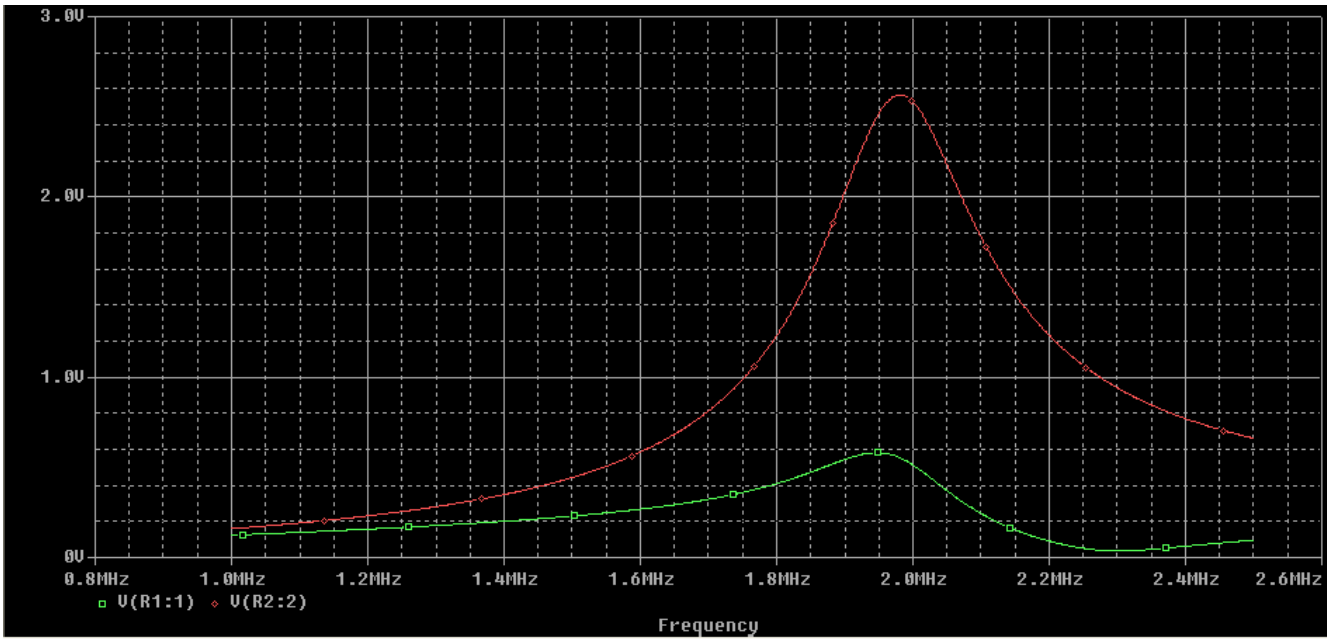
Figure 3. Equivalent schematics for matching line, used for simulation.



Calculated frequency response is presented on the **Figure 4**. Here, the colors of the traces correspond with the colors of the voltage markers on the schematic. As it can be seen, on the resonant frequency about 1.95 MHz there is sharp voltage maximum on R2 (red trace), which reaches 2.6V – it is about 5 times more, than the voltage on the transmitter's output (green trace). Also it should be noted, that on the resonant frequency voltage on R1 (green trace) is closed to one half of source voltage (in our case, 1V). Practically, it means, that there is good matching between transmitter and the "antenna" and most of generated power is dissipated on the loading.

After the resonance has been found, it should be shifted up to the desired frequency. To do this, the end of the cable should be cut carefully in several steps, watching the resonance frequency each time, which must increase with each cut. After you achieve the desired frequency, the matching line is almost ready, and you can mount the whole antenna system in the chosen place. It should be noted, that the minimum of the SWR in mounted antenna is usually 20-30 kHz down, compared to the value achieved by the tuning on the resistor.

Figure 4. Frequency response of the matching line in range 1 – 2.5 MHz



In my case, the antenna for 160 m band had a minimum of SWR at 1875 kHz (about 1.3:1), on the edges of the band SWR increased to 2.0…2.5:1, since the design is a narrow-band one. Compared to my previous dipole, which hanged on the low height (about 5 meters over the ground) along the building, this antenna exhibited much better transmission efficiency and higher signal to noise ratio while receiving.

The same design for 10 meters - cheap and simple.

About 2 years after getting my first amateur license I upgraded it to the higher license class, which allowed me to operate on 10 meters SSB. In that year, there was a perfect propagation on 10 meters band during the daylight time, and I needed an efficient antenna to work on it. Probably, in some time I will have something like rotable multielement Yagi on my roof, but now it seems to me inaccessible as the Moon due to many factors. After some time I decided to repeat what I built for 160 meters for 10 meters, proportionally reducing all geometrical sizes of the antenna wire and matching line.

Since the wavelength on 28500 KHz is just 10.52 m, a half-wavelength dipole should be about 5 meters, and the total length of the coaxial matching line will be 10.52/(4*1.52) = 1.73 m. The feeder is connected to the line 23 cm away from the shortened end. These sizes are relative small and the whole antenna system may be placed without being mounted on the roof, for example just from your window to the neighboring tree.

I made the antenna from a 2 mm copper wire with a plastic insulators at the ends, using 75 Ohm coaxial cable for feeder and matching line. There was nothing difficult to tune the system - I hanged the antenna across my apartment and adjusted the length of the matching line as described above for 160m design using 1.80 m as the starting value. The only thing that should be noted is that the actual resonance of the line is very sensitive to the length variations, so on the final steps the cable should be cut in 1 cm (!) portions or even less to not miss the desired resonance position. After I hanged the antenna on the designated position, SWR was less then 1.5 on all frequencies ranging from 28200 to 29000 KHz.

This antenna is really very simple and cheap, but nevertheless, I allowed me to establish many connections with Europe and even Far East using just about 10 Watts of power. I really enjoyed working on 10 meters ether in local communications and transnational QSOs, and this was made possible just by several hours of time, dedicated to the antenna building and tuning.

About working on other bands – some facts and theory.

Though LW antennas with a feeding through coaxial transformer, which were described above, seem to be monoband, this appeared not completely true. As I found out, the whole system has many resonant frequencies, and some of them, are inside or near amateur bands and can be used for working on these bands.

As it could be expected, operation on the frequencies, which are twice more that ‘native’ ones, is impossible. When using an antenna for 160 m, on 80 m band observed SWR is closed to infinity and the transmission efficiency is not more that by using a random wire with length of several meters... Simply it can be understood, that on doubling the working frequency the matching line is completely out of resonance, and works as a “short” for the transmitter. But everything has advantages, and this fact means not only impossibility to work on 80 m, which is definitely bad, but also deep suppression of 2- nd harmonic by working on 160 m, which is really well.

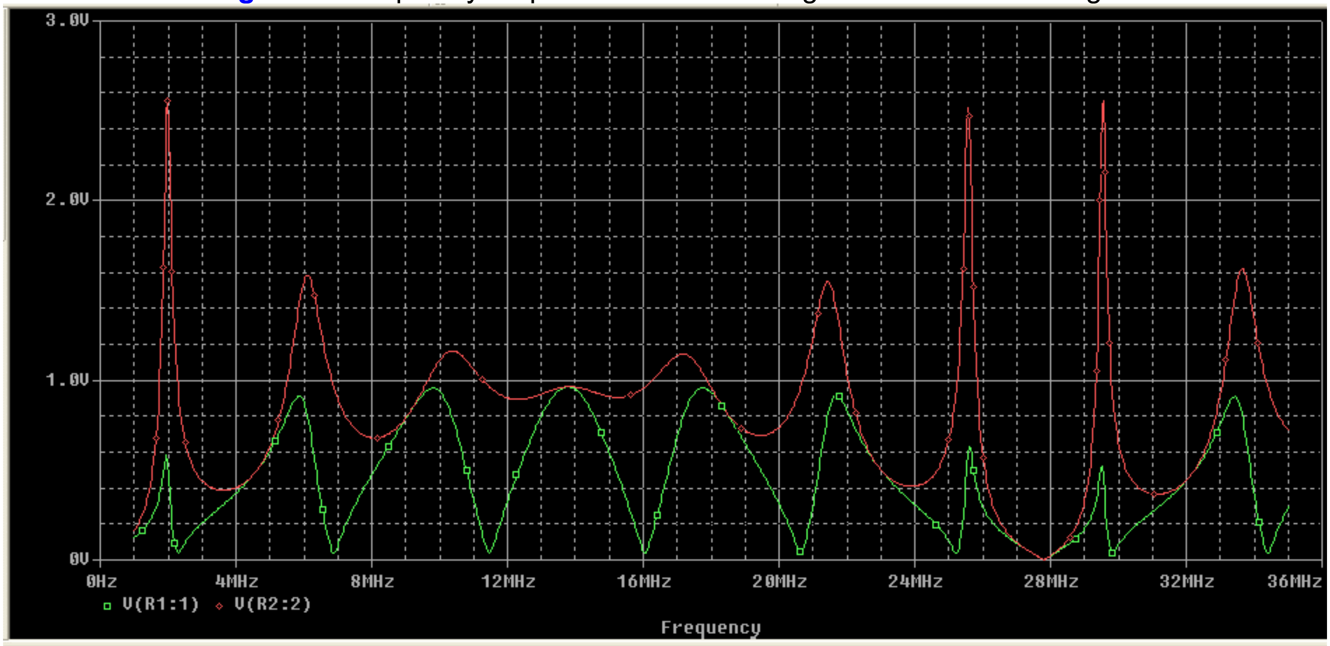
Almost the same situation is on 40 m band. Here the active component of input impedance of the antenna (measured by noise bridge) is also quite low (several Ohms), and no resonance exists inside or near amateur frequencies.

But if you try to work on this antenna on 15 and 10 meters bands, the situation is more optimistic. In my case, on 21430 KHz the SWR was about 1.3:1 and increases to 2.5:1 when moving down to 21000 KHz. Measured impedance was about 55 Ohm with a low capacitive reactance. From first sight, it is quite strange, but nevertheless, antenna behaved well on this band, and using just 10 W of power, I was able to make long-distance QSO’s even with North America. The most interesting fact was, that this was “true” resonance of the antenna, without any participation of the feeder (SWR did not change significally when the feeder length was alternated).

In contrast to this, on 10 meters band the antenna behaves very poor – the air seems to be “empty”, and even common industrial noise is received with a level comparable to internal noise of the receiver. Compared to the special 10 meters antenna (see above), the signal of distant correspondents were weaker by 10-20 dB (!), and on transmission even my neighbors gave me reports like 53-54. However, when frequency was moved up to 29 MHz and higher, the efficiency improved dramatically.

To understand this phenomenon, some calculations were performed. First of all, it was found, that frequency response of the matching line with a resistive loading (see **Figure 3**) in range 1.5 – 32 MHz has many maxima, and one of them is inside 15-m amateur band (**Figure 5**, red trace). Another maxima is near 29.5 MHz – in the upper part of 10-m band.

Figure 5. Frequency response of the matching line in whole HF range



I guess, that these results may be assumed at least as a qualitative explanation of the antenna behavior. I say “qualitative” because the whole system can not be adequately represented by a matching line with a resistor at the end – impedance of the antenna wire also should be taken into account. However it is clear, why besides ‘native’ band, antenna works well on 21 MHz, and why on frequencies about 28500 there is a minimum of performance, which rapidly increases when moving up to 29 MHz.

Conclusion

As a conclusion is can be said, that LW antenna with a coaxial matching line (J-antenna), which is designed for 160 m band, can do perfect job on 15 meters and on a part of 10 meters band also without any switching and tuning devices. Of course, the efficiency on ‘upper’ bands is be substantially lower, that on ‘native’ one due to RF losses in the matching line (which actually works with a very high SWR). But to my mind it is still acceptable, especially in the case, when there are no conditions to mount huge and efficient antennas.