

Impact of Resonant TX antennas on the Radiation Pattern of RX Directional Antennas. Detuning of TX Antennas.

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1. Models

2-element small loops and 2-element small dipoles arrays (wideband) are modeled with MMANA program [1]. The arrays are with vertical polarization placed at low height above the ground. All models are above real ground setup with (Eps=13, Sigma= 5 mS/m). The impacts of two (vertical GP and horizontal dipole) resonance antennas (called TX antennas) are estimated (Fig.1). The sources are in the RX array but this does not matter, since the transmitting radiation patterns and the receiving patterns are the same. The pictures are self explaining.

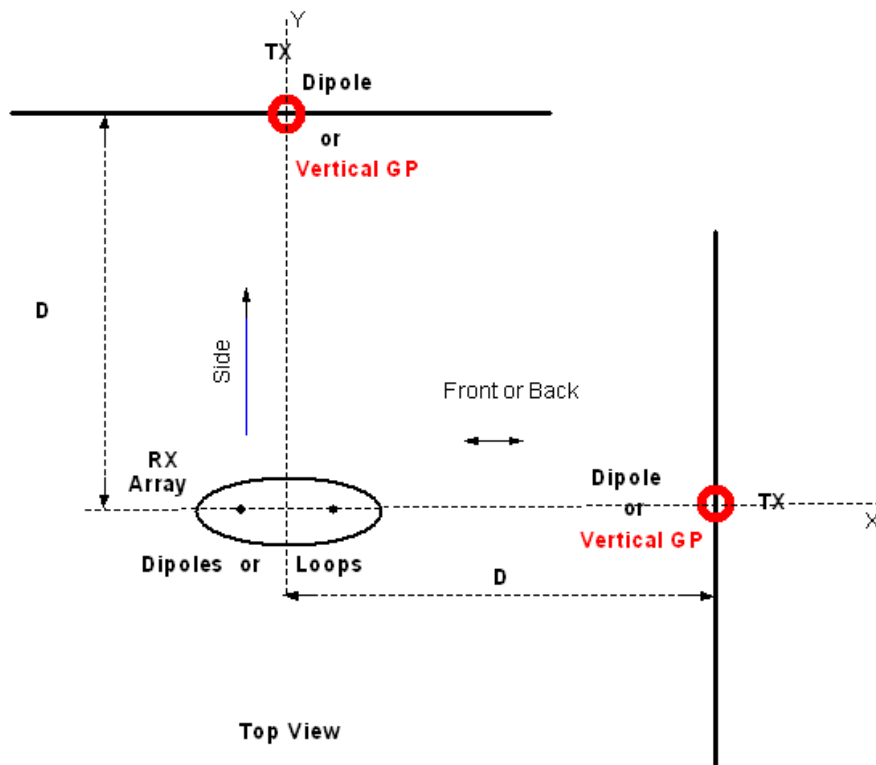


Fig. 1 MMANA model. A TX antenna is placed in the vicinity of a 2-element RX array. Distance D and placement between them is variable in order to estimate the degree of impact. D is from 0 to 160 m. Horizontal dipole and vertical GP (red) are modeled.

Dipole elements are 5 m long. The centers of the dipoles are 3 m above the ground level. The distance between elements is 14.5m (X axis). The frequency is 1.825 MHz. The time delay between sources is set to optimal [1]. Loop elements are quads with 1 m side with 14 mm diameter of the conductor. The centers of the loops are 2.5 m above the ground level. The distance between elements is also 14.5m.



Fig. 2 Loop array pattern without impact

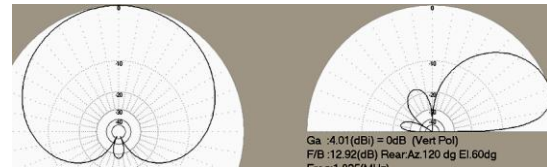


Fig.3 Dipole array pattern without impact

The first TX antenna is a vertical GP with length 22 m and tuned to resonance with additional inductance of 27 uH. The lower point is at MMANA level 0 m without radials. The other TX antenna is a horizontal dipole 2x39 m at 20 m height.

2. Impacts

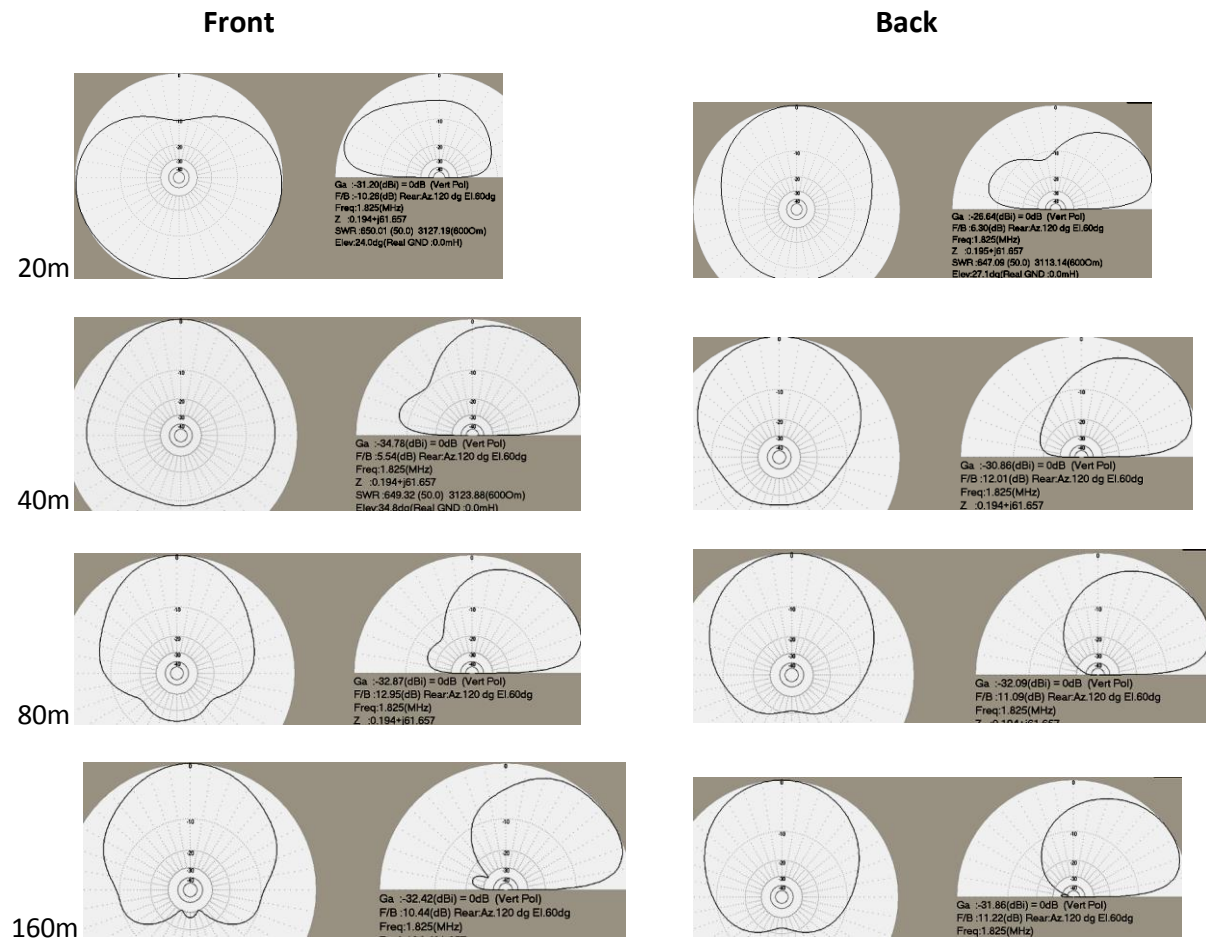


Fig.4 Loop array. Impact from TX Vertical GP. The distance D is denoted at the left side of the pictures. 'Front' means that the TX antenna is placed in the direction of maximal gain of the RX array. 'Back' is the opposite direction.

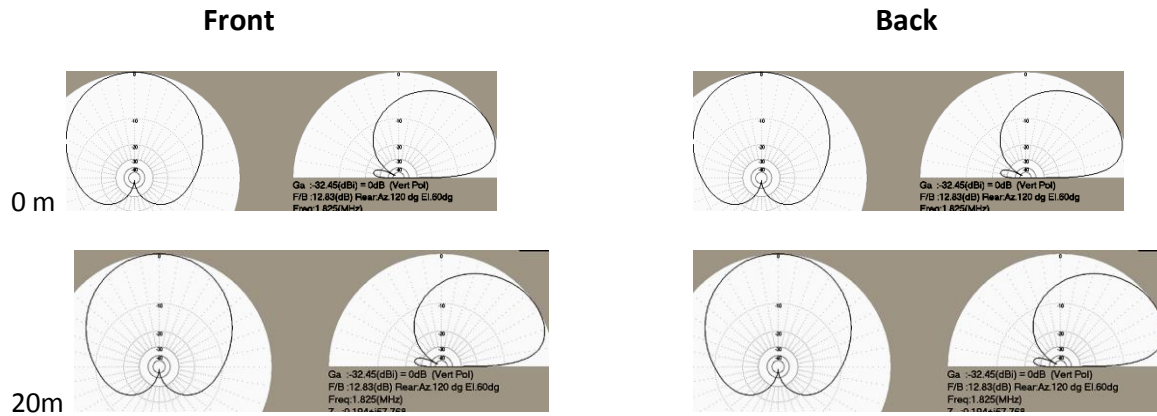


Fig.5 Loop array. Impact from TX horizontal dipole . Practically the impact is zero. 0 m means that the dipole is just above the array at 20 m height. The reason for that is the polarization mismatch. The RX array has vertical polarization and the horizontal dipole has pure horizontal polarization at the direction normal to the dipole wire.

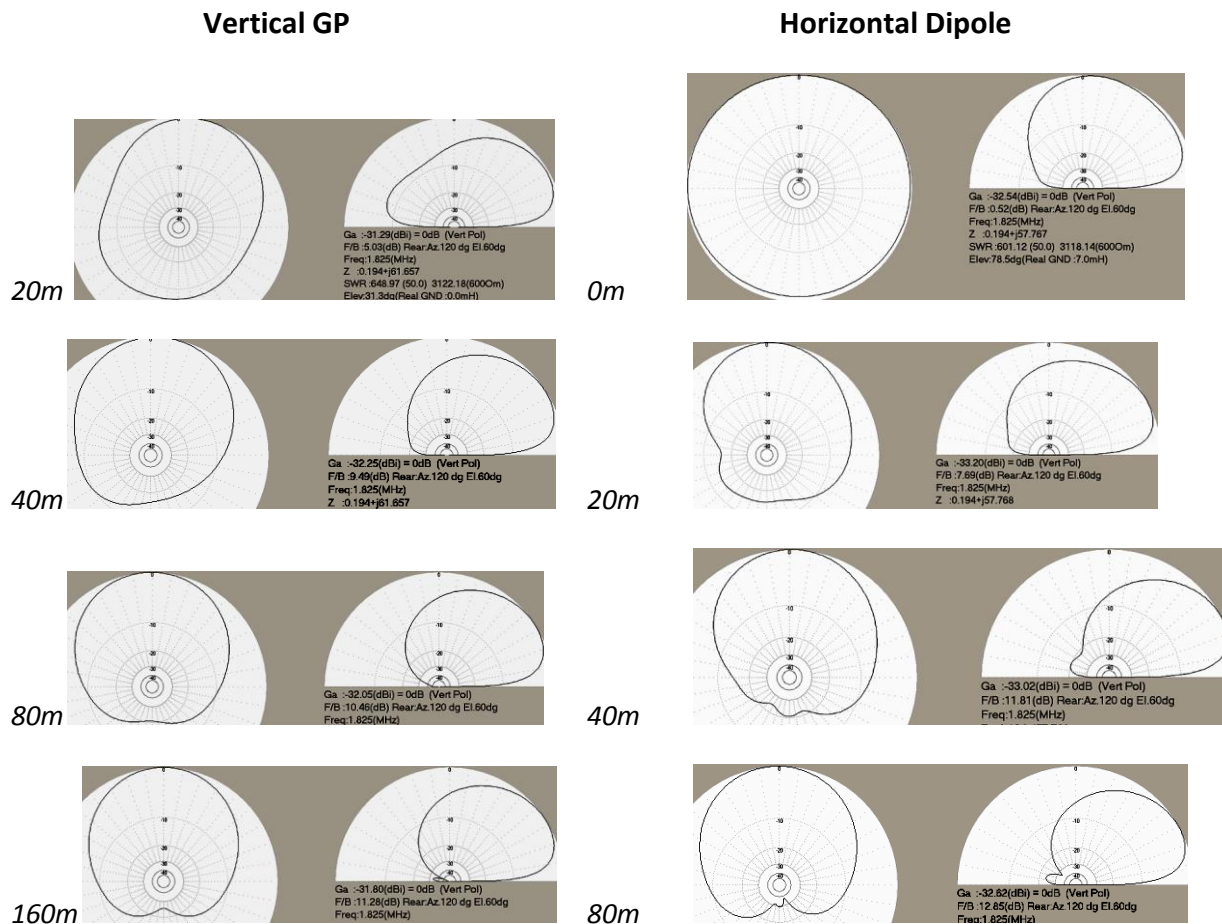


Fig.6 Loop array. Impact from side location of the TX antenna.

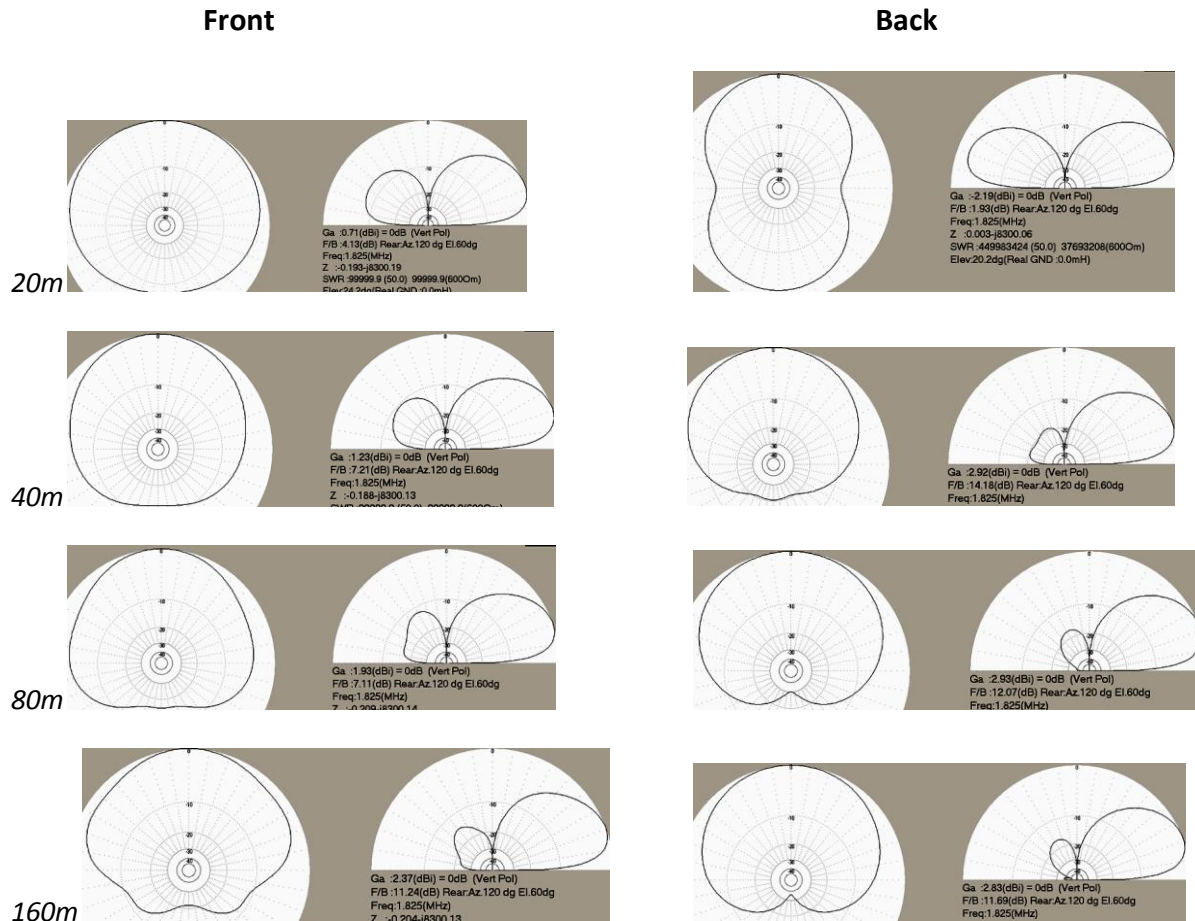


Fig.7 Dipole array. Impact from TX Vertical GP.

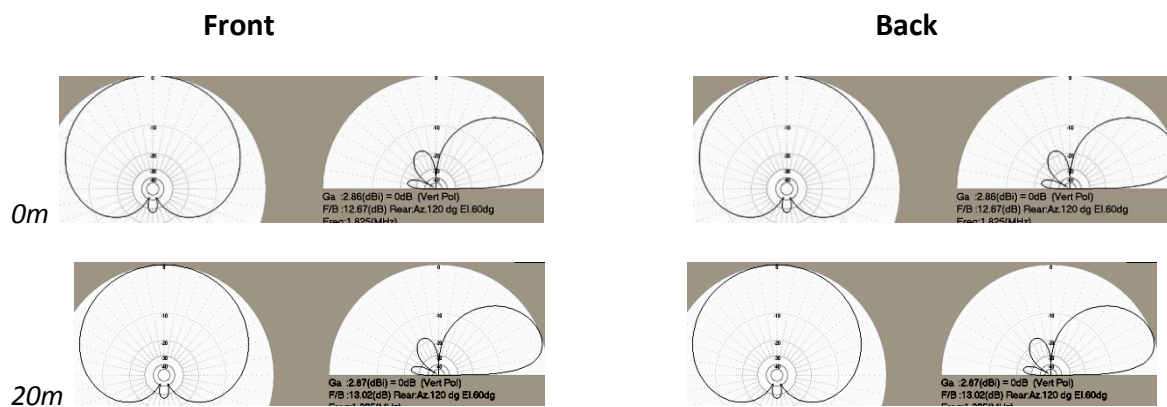


Fig.8 Dipole array. Impact from TX horizontal dipole. 0 m means that the dipole is just above the array at 20 m height. Practically the impact is zero. The reason for that is the polarization mismatch. The RX array has pure vertical polarization and the horizontal dipole has pure horizontal polarization at the direction normal to the dipole wire.

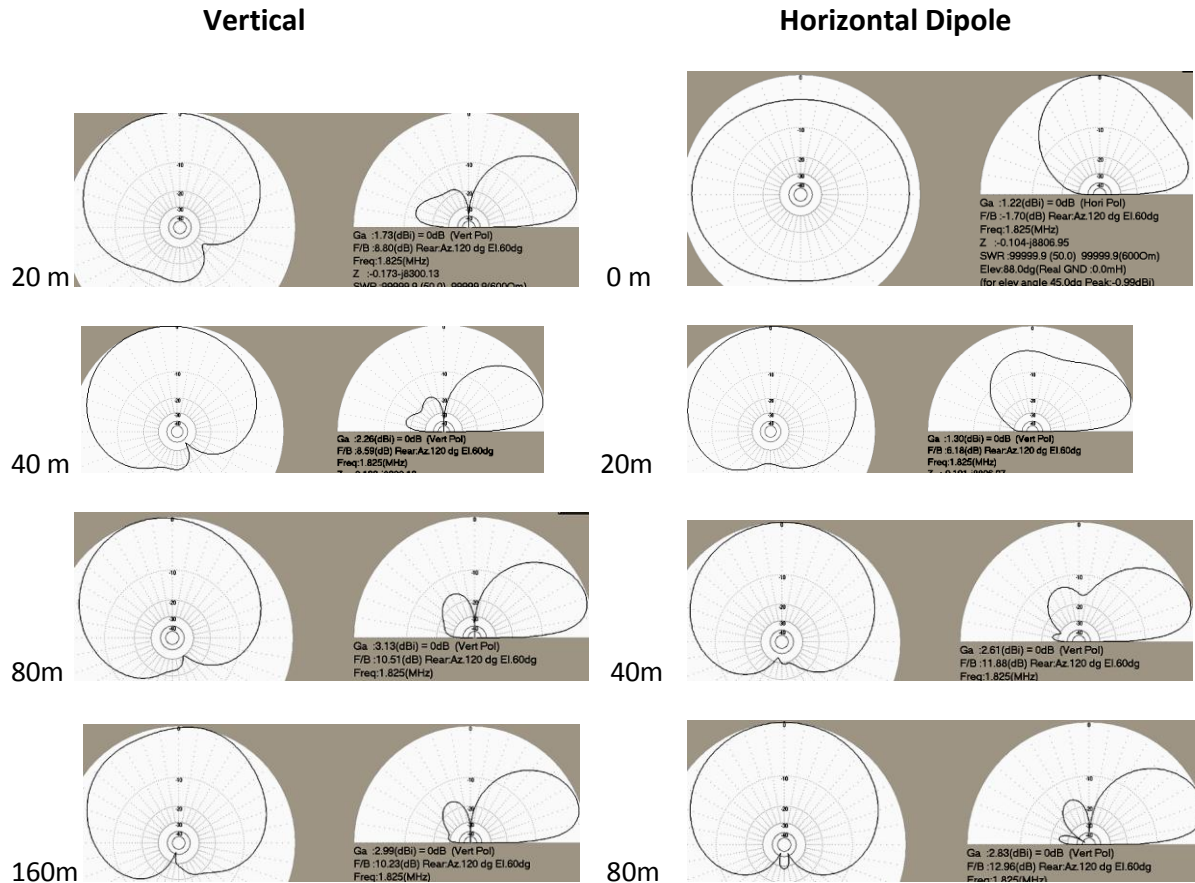


Fig.9 Dipole array. Impact from side location of the TX antenna.

3. Detuning the TX antennas

The effects of detuning the TX antennas are shown on the Fig. 10, 11 . Different complex impedance loads connected to TX antenna terminals move the resonance away . The best way is to disconnect the feeder thus opening the TX antenna terminals. In this way the TX antenna is divided into two parts each WL/4 length (WL = wavelength) . We need 2 pole RF high power relay to disconnect the feeder from the antenna terminals . Both the braid and the central conductor must be disconnected.

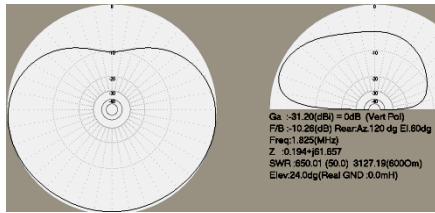
There is another way – to detune the antenna from the feeder . The idea is to disconnect the feeder from TRX and load it with some reactance X which will give at the antenna side high impedance $|Z_A|$. This is always possible but we must choose the proper detuning reactance at the TX side. We can do it by trial and errors method but we must measure feeder the impedance in the antenna side.

Fortunately there are programs that can calculate this impedance very accurately. I have used TLD program [2] for this purpose. Choose your feeder type, set the length and the frequency and then begin to change the load impedance trying to reach high impedance magnitude $|Z_A|$ at the other feeder end. Set the R=0 and change only X of the load impedance. This procedure is actually searching a parallel resonance point at the other feeder end by changing the reactance at feeder input. For low impedance coaxial feeders, magnitude of $|Z_A|$ higher than 500 ohms is usually sufficient to detune effectively closely spaced TX antennas. The maximal magnitude $|Z_A|$ at the resonance at the cable end

depends from the cable length, its losses and operating frequency. The longer the cable the smaller is $|Z_A|$ in resonance but in any case this type of detuning will work.

Important note: if a balun is connected between the feeder and the antenna terminals the length of the coaxial cable in balun windings must be added to the feeder length.

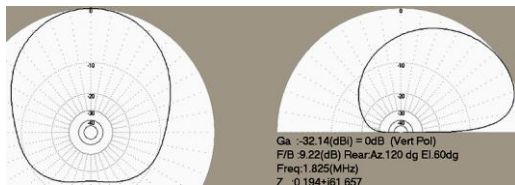
Vertical GP in front direction



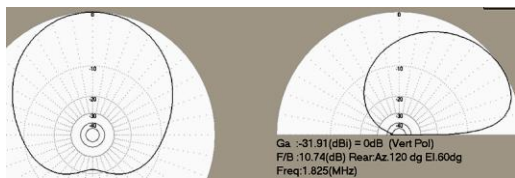
27 uH 1.8 MHz



10 uH, 2.4 MHz



0 uH, 3.4 MHz

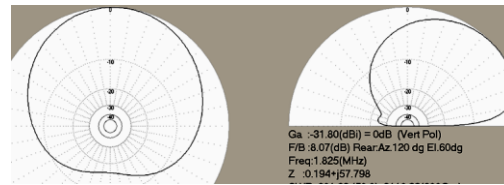


Open circuit

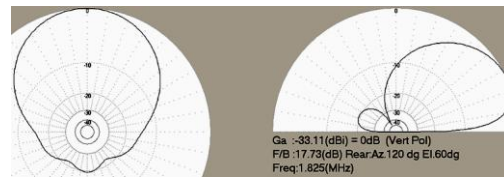
Horizontal Dipole in side direction



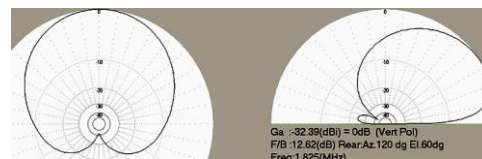
75 + j0 (matched)



75-j200 (capacitive)



75+j200 (inductive)



10000+j0 (open circuit)

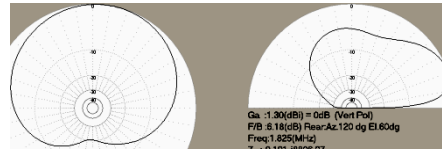
Fig.10 Loop array. Effect of detuning when $D=20$ m. The strongest impact is when the TX GP is in front direction or the TX dipole is in side direction of the RX array. The inductance of the vertical GP is reduced and the resonance is shifted to higher frequency. For the horizontal dipole, different complex impedance loads are connected to the dipole terminals.

Vertical GP in front direction

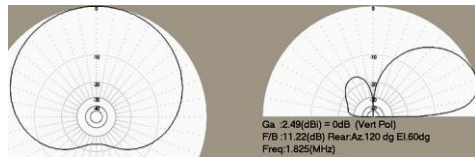


27 uH 1.8 MHz

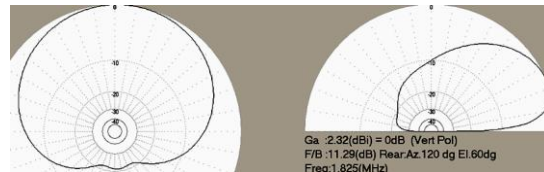
Horizontal Dipole in side direction



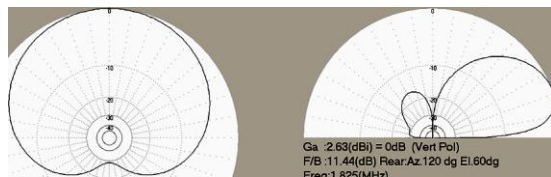
75 + j0



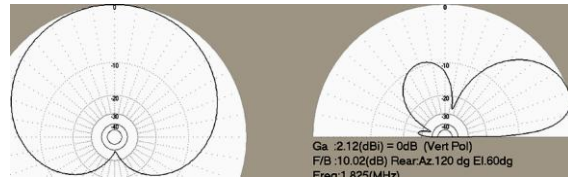
10 uH, 2.4 MHz



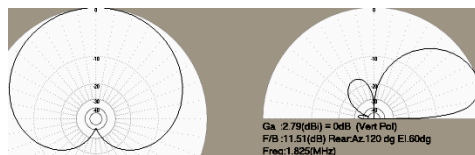
75-j100



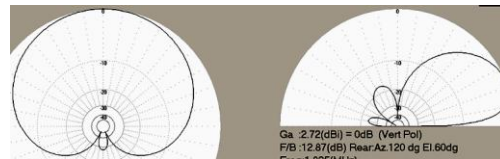
0 uH, 3.4 MHz



75+j200



Open circuit



10000+j0 (open circuit)

Fig.11 Dipole array. Effect of detuning when $D= 20$ m. The strongest impact is when TX GP is in front direction or TX dipole is in side direction. The inductance of the vertical GP is reduced and the resonance is shifted to higher frequency. For horizontal dipole, different complex impedance loads are connected to dipole terminals.

This proper reactance load must be verified and trimmed if necessary by measuring the impedance magnitude at the antenna side. Any VNA or RF bridge can be used for this purpose. I have used a very simple setup shown on Fig.12. At the resonance point the measured power (voltage) is minimal. Since at this point $|Z_A|$ is pure resistance there is a simple equation to calculate its magnitude:

$$|Z_A| = 50(V_S/V_M - 2) \quad \text{in ohms}$$

where V_S is the signal generator output voltage (open circuit) and V_M is the measured voltage by the power meter. (These voltage are recalculated from the power levels in dBm.)

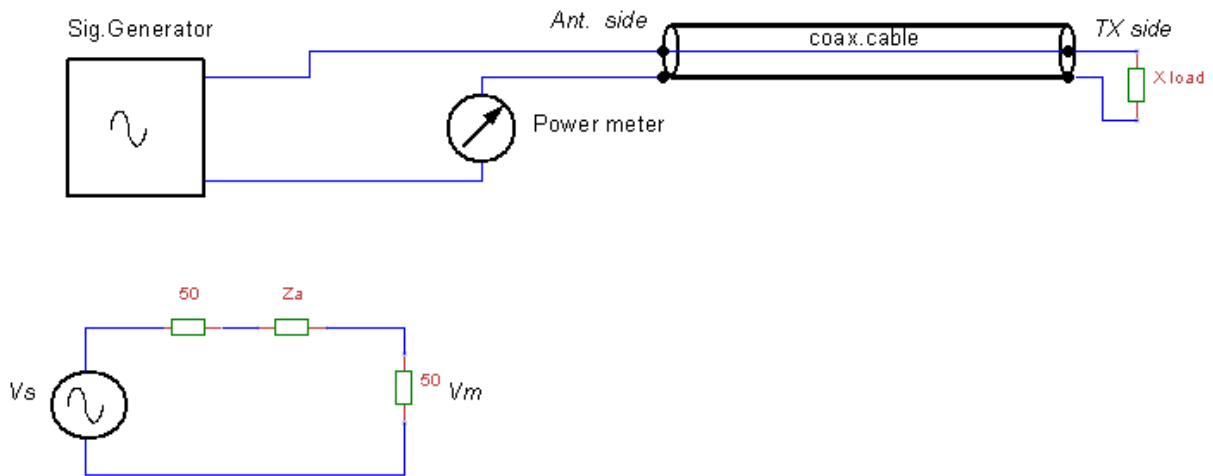


Fig.12 A setup to measure the optimal detuning load. A signal generator and a simple power meter (described in [3]) are used. This power meter is very sensitive and the level from signal generator can be low (from -30 dBm to 0 dBm). The optimal load reactance is when the meter shows minimal power. At this resonance point the Z_a is resistive and the equivalent schematics is shown.

4. Detuning resonance wires

Other cases are when low height wires with resonance length are passing near the array. This might be a feeder or some power cable etc.

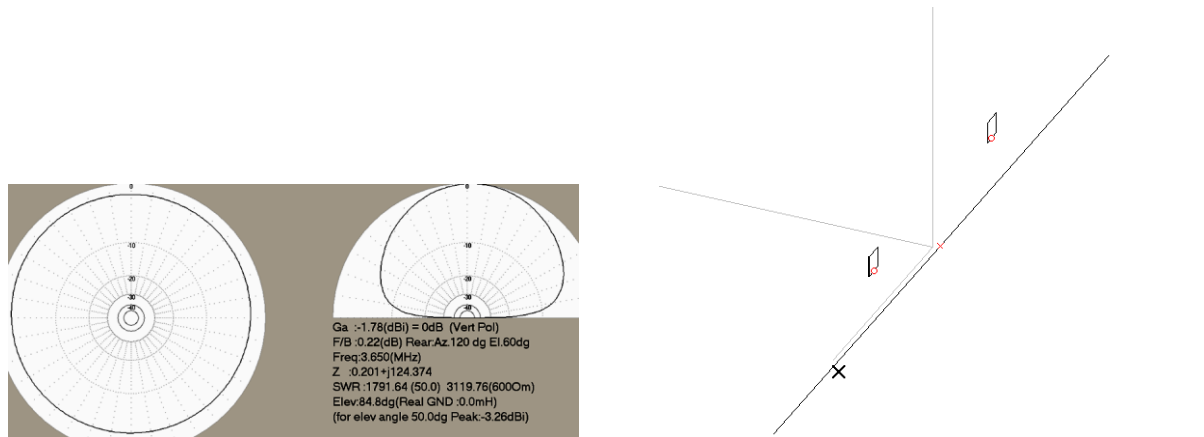


Fig.13 A resonance $WL/2$ wire 1m parallel to the loop array and 1 m above the ground.

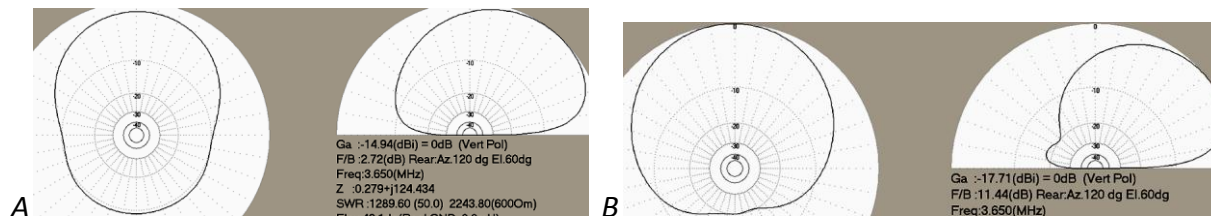


Fig.14 **A** - The same wire 0.1 m from the ground, **B** - The same wire as A but 5 m from the array

Obviously the lower the wire the less is the impact. I can not say what is the impact when the wire is laying on the ground. (MMANA gives strange current distribution when the wire is less than 10 cm from the ground).

The cure of this problem is to split the wire into smaller than $WL/2$ segments by the means of common mode baluns - Fig.15 . The balun impedance must be higher than 200 ohms at the resonance frequency if the balun is inserted at current maximum point of the cable. Unfortunately it is difficult to find this point. The best strategy is to insert at least two baluns at the cable on a place which is nearest to the array. The distance between the baluns must be $WL/4$.

Bear in mind that a resonance wire might be the feeder of the RX array itself. If its common mode length is multiple of $WL/2$, it might influence the array in the same way as any other resonance wire. The common mode velocity factor of the cable is usually not known and we can not simply resolve this problem by avoiding multiple of $WL/2$ cable lengths and again common mode baluns must be used.

All these measures must be taken if the cables are more than 0.5 m above the ground. For cables laying on the ground probably no special measures must be taken.

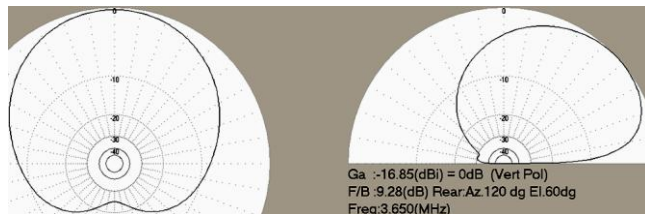


Fig. 15 The same case as in Fig. 13 but at the current maximum (center) is inserted impedance of $Z= 200 + j200$ ohms which simulates a common mode balun.

5. Examples

An example of a very common case is shown on Fig.16 . An RX array with two short vertical dipoles and a closely spaced $WL/4$ resonant GP with 4 elevated $WL/4$ radials. The interesting point here is that a pair of radials form a wire with $WL/2$ length. Irrespective of the feeder detuning, the radial system has its resonance frequency and there the pattern of the array is totally destroyed.

The best way to avoid this problem is to use shorter radials which will move the radial system resonance away. Slightly longer radiator or additional inductance or capacitive hat will tune the antenna back in resonance and the feeder detuning will work.

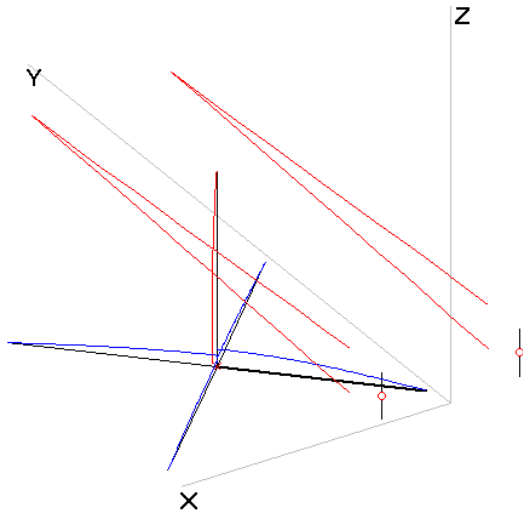


Fig. 16 A detuned GP with resonance elevated radials 1 m above the ground. $F=3650$ KHz. The vertical radiator is 21 meters in diagonal direction from the center of coordinate system. It is connected to common radial point through 500 ohms resistor which simulates the impedance of a feeder tuned to resonance at the feeding point.

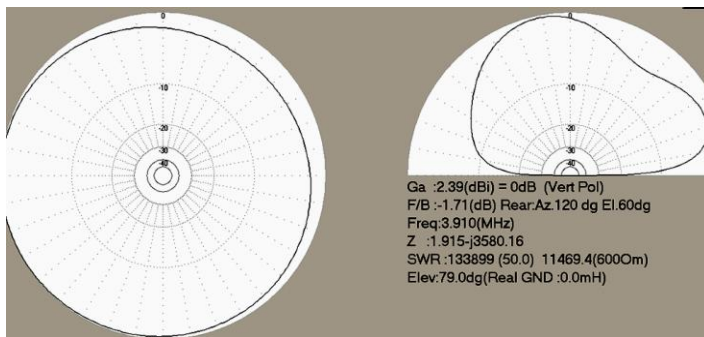


Fig.17 Dipole array pattern with detuned vertical radiator but the radial system in resonance.

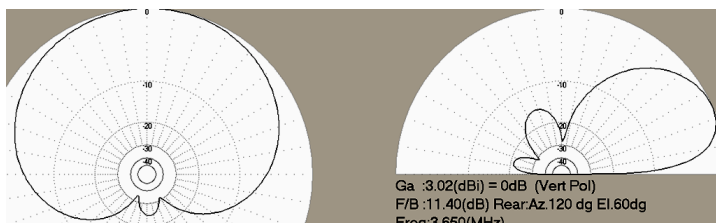


Fig. 18 Dipole array pattern with detuned vertical radiator but with radials shorter with 10% from resonance length.

Here is another practical example: I have in my small yard (20m x 15m) a GP for 80 m band with 6 elevated very short radials (7.5m). The radiator is sloping, with length 16 m, loaded with small inductance at the bottom and with two capacitive wires at the top ; There is also a directional 2-element RX antenna with small active loops spaced at 12.5m, which are only several meters away from the GP and between radials (Model at Fig.19) .

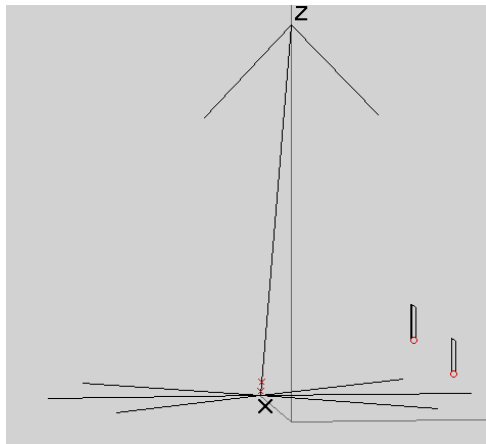


Fig.19 MMANA model of GP and RX array

The length of the coax. cable is 20 m (type Andrew CNT300) to the shack. At the feed point there is also a balun (350 uH) on a ferrite core winded with 2.5 m length of the 50 ohm Teflon coax.cable . The frequency in TLD program was set to 3.65 MHz. I set the cable length to 22.5 m. The feeder far end resonance point was reached with load impedance of -30 ohms. There $|Z_A| = 1300$ ohms. $X_c = -30$ ohms is equivalent to capacitor of 1450 pF at this frequency. Fig. 21 shows the effect of detuning with 1450 pF also at band edges. The measurements give a resonance value of 1700 pf which is close to the computed one.

If we use similar 20 m coaxial feeder for another TX antenna for 40 m band then the detuning impedance must be $X = +96$ ohms, which at 7.1 MHz is inductance of 2.15 uH. $|Z_A| = 1420$ ohms at the feeder antenna end. With the same feeder for 1.84 MHz we have $X = 37$ ohms, $L = 3.2$ uH and $|Z_A| = 4430$ ohms. One possible practical solution is shown of Fig.20.

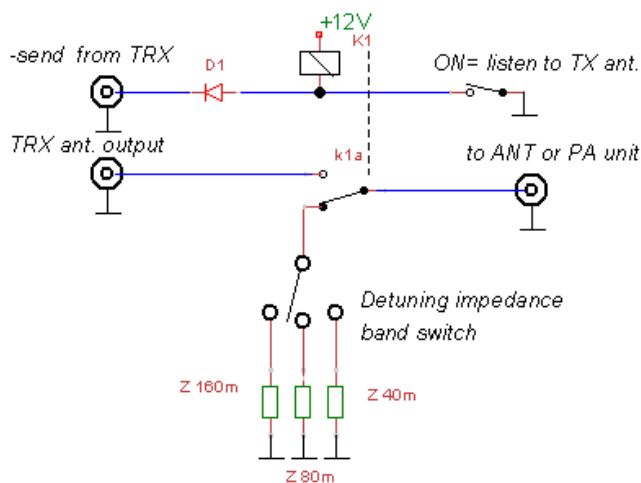


Fig. 20 Detuning switching scheme. Each band need to have different detuning reactance. Every TRX has ‘-send’ signal which is connected to ground when in TX mode. When ‘-send’ is in high impedance state the detuning reactance is connected to the feeder. In TX mode this reactance is disconnected.

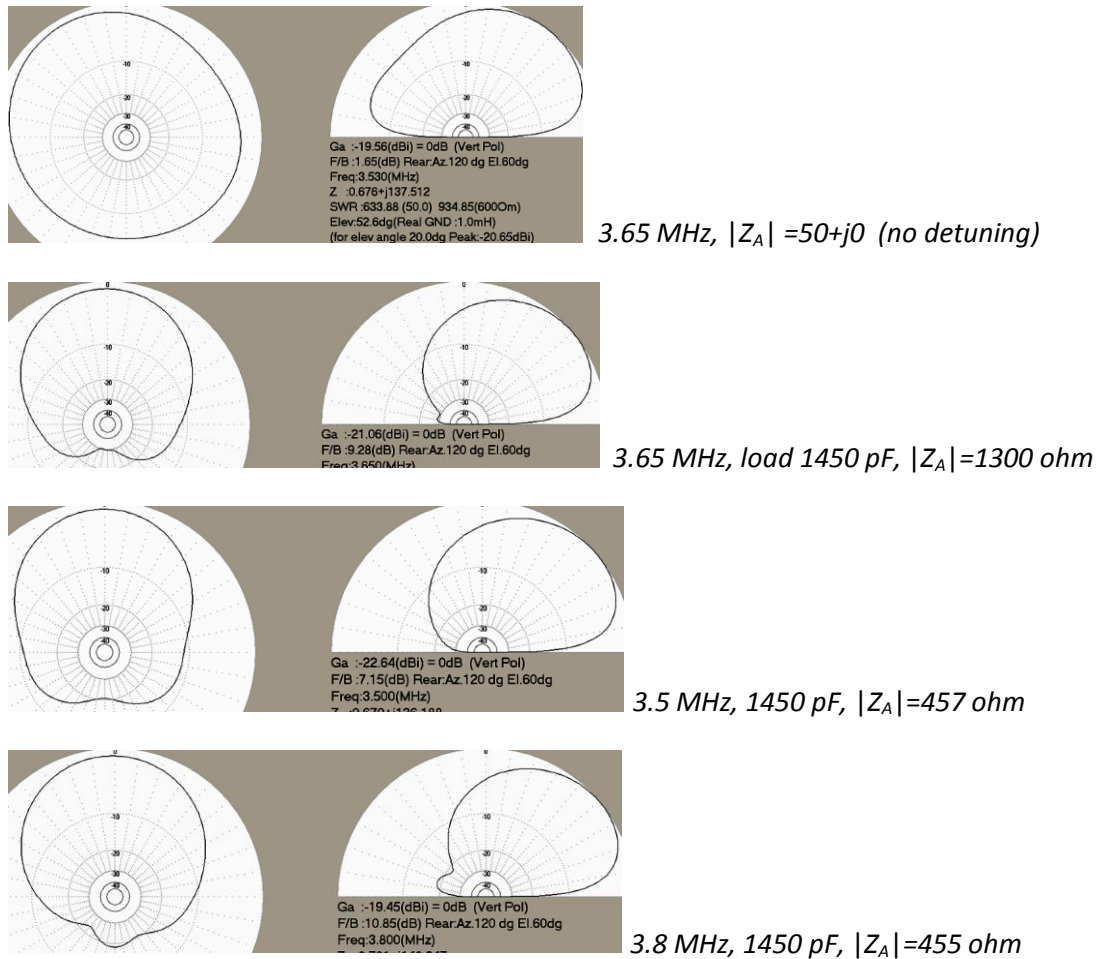


Fig. 21 Modeling the practical example of very closely spaced TX GP and RX loop array (Fig.19) . Effect of detuning at coaxial feeder end with 1450 pF capacitance.

6. Conclusions

- Resonance antennas have strong impact both on loop and dipole arrays. The radiation pattern of the RX array is distorted significantly.
- Distances at least from $WL/2$ to $1.5 WL$ (depends on mutual placement) are needed if the TX antennas are not detuned.
- Horizontally polarized TX antennas have minimal impact on the vertically polarized RX antennas. But the problem is that the full sized horizontal antennas do not have pure horizontal polarization in different directions. Also the loop RX array has some horizontal component.
- The degree of sufficient detuning depends from the distance D. For antennas of $WL/2$ type, the best way is to disconnect the feeder thus opening the TX antenna terminals. In this case the TX antenna can be very close to the RX array.
- Detuning from the feeder end is the easiest way. When properly done it is equivalent to disconnected feeder.

- Large terminated travelling wave antennas (as beverage), even with resonance length and placed very close, do not impact the RX array. If not terminated, and with resonance length, the impact is as with any resonance TX antenna.
- Feeders and other cables must be laying on the ground and be as far as possible from the RX array. If this is not possible and we suspect parasitic resonance, a detuning with common mode baluns must be implemented. Balun impedance must be higher than 200 -300 ohms at the resonance frequency if the cable is too close to the array elements.
- It is good practice to insert common mode baluns into RX array feeder in order to avoid incident common mode resonance. The other benefit from that will be the reduced conducted noise. But probably the best way is to bury the feeder into the ground.
- These models cannot predict accurately what the real world will serve. But probably these rules are valid and can be applied to other RX antennas as Flags, K9AY, large RX arrays etc. Making models of the environment is a good way to understand sometimes unexpected behavior of our RX antennas.

7. Links

[1] http://www.lz1aq.signacor.com/docs/phased-array/2-ele_phased_array11.pdf

[2] Transmission Line Details, <http://www.ac6la.com/tldetails1.html>

[3] Wes Hayward, W7ZOI, and Bob Larkin, W7PUA, Simple RF-Power Measurement, QST June 2001 p.39