Managing Field Day Interstation Interference by Antenna Configuration

The issue of Field Day interstation interference and contest station interference where multiple rigs are operating simultaneously at the same site is a common problem. George Cutsogeorge's (W2VJN) book [1] on interstation interference is a great resource on this problem. The NCJ also published a 2-part series on this problem in Sept and Nov of 2010 by Barrett Milliken, KC9CHG, and Tim Toman, N9TO [2 & 3]. For Field Day, antenna placement and configuration can be a key part of the solution to interstation interference. Of course, filters for each HF operating band are an important part of inter-band solutions. Using EZNEC simulations and field measurements, we clarify several key techniques to isolate antennas, especially for operating on the same band for Field Day such as CW, Phone, Digital and GOTA stations with intra-band interference where filters generally cannot separate the signals. In particular, the tilting of dipoles can significantly enhance isolation by nulling coupled signals for some configurations. Furthermore, unequal tilting of the two sides of a dipole is important to achieve the best performance in those situations. Using antennas with different polarizations can provide excellent isolation, such as a vertical broadside to a dipole or to an inverted vee. We show that it is possible to configure 3 antennas on a single band with very high isolation between all of them limited only by non ideal properties of the environment and of the antenna placement by using polarization and antenna tilting.

Here are recommendations you might find on addressing interstation interference: [4]

1) Maximum antenna separation
2) Dipoles that are oriented end-to-end
3) Different polarized antennas such as a vertical and a horizontal dipole
4) Try moving the antennas …. until you find the deepest null
5) Mono-band antennas to minimize coupling on undesired bands
6) Baluns or RF chokes to minimize radiation from coaxial feed lines
7) TX/RX filters to suppress TX noise and mitigate RX overload for inter-band interference
8) Separate power generators or RF chokes to eliminate coupling in the power lines between rigs
9) Strong grounding with separate ground connections for rigs or "star" configured RF bonding
10) Disable RX preamps and enable RX attenuators
11) Use QRP as much as possible to minimize interference

Several top Field Day clubs published their techniques in 2009 at the Dayton Hamvention [4 & 5]. W3AO operated with 23 transmitters in 2008. W3AO used Elecraft K3 rigs which are high end and provide very good TX noise and RX blocking performance. A key technique used by W3AO was Yagi's on 40 through 10 meters at 50 feet in height all facing west from the east coast which placed the Yagi's in each other's side lobes. That does provide excellent isolation on the same band. EZNEC simulations of 2-element Yagi's on 40 meters separated by 300 feet and placed at a height of 50 feet with a side-by-side orientation show an isolation on the order of 70 dB. W3AO used end-to-end dipoles on 80 and 160 meters which may provide less isolation on the order of 50 dB, but on those bands, high levels of atmospheric noise allows the use of significant RX front end attenuation which helps with isolation.

Large differences in interstation interference for some rigs are noted by hams. Solid state TX's using digital synthesizers can generate strong wide band noise compared to old tube equipment using analog VFO's. This appears to be less of a problem with modern solid state equipment but large differences between equipment may exist and this issue should be considered. Some note that solid state RX's can be sensitive to overload. This also appears to be less of a problem with modern solid state equipment and can also be mitigated by disabling RX pre-amps. The use of RX/TX filters is important to suppress inter-band synthesizer and phase noise as well as harmonics transmitted along with desired signals and to prevent blocking and intermodulation (overload) problems at receivers. But if you plan on operating several stations on the same band simultaneously such as a CW, phone, digital or GOTA stations, antenna isolation is a key solution to interstation interference.

Only fixed antennas using verticals, dipoles and inverted vees are considered here. But it should be possible to include fixed arrays for consideration using similar analysis. The use of rotating Yagi's or other movable antennas results in a more difficult situation since isolation will depend on the direction of the movable antennas, but fixed Yagi's placed end-to-end can provide high levels of isolation. Nevertheless, certain techniques would be helpful a situation with rotating Yagi's such as using a vertical for one station and a rotating horizontal Yagi for a second station to achieve polarization isolation.

The NCJ 2-part series on this problem in Sept and Nov of 2010 by Barrett Milliken, KC9CHG, and Tim Toman, N9TO considered using different polarizations to isolate antennas on the same band. The use of polarization to isolate antennas is a fundamental property, and several configurations are presented here similar to some of the configurations presented in the 2010 2-part series.

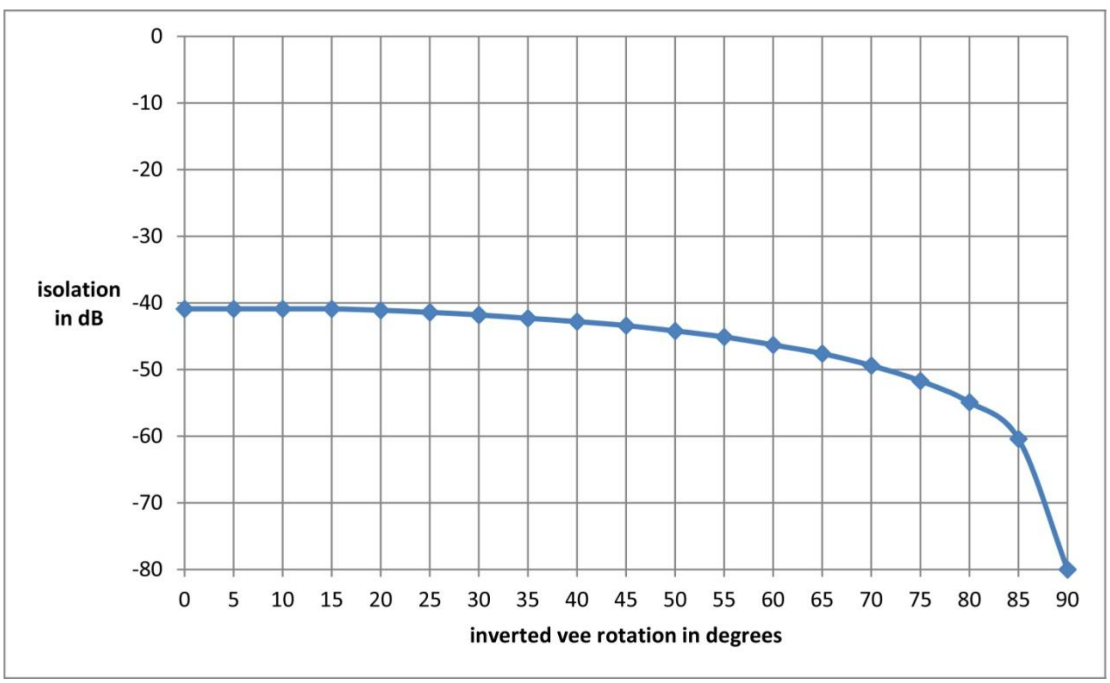


Figure 1: Isolation of Inverted Vees versus angle

Figure 1 shows the isolation between 2 inverted vees on 40 meters modeled with EZNEC. A deep null is achieved when they are oriented at 90 degrees or perpendicular and so in different polarities while maximum coupling happens when the inverted vees are end-to-end. The antenna centers are separated by 300 feet with the centers at 30 feet above ground and end points 7 feet above ground.

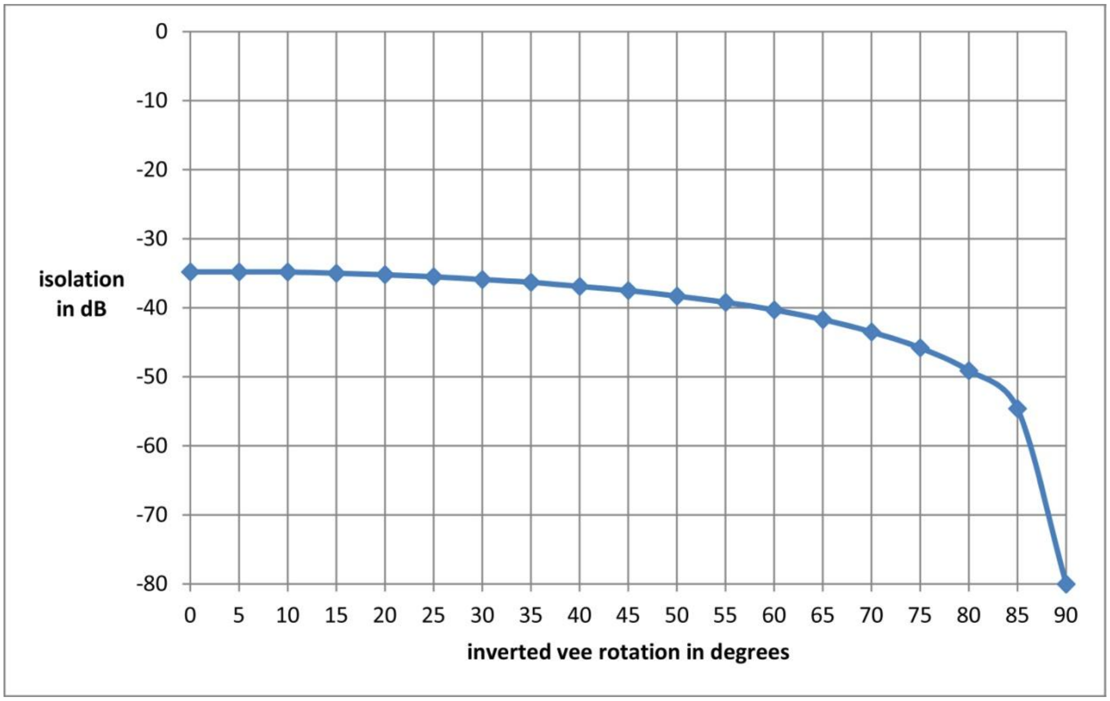


Figure 2: Isolation between a vertical and an inverted vee versus angle

Figure 2 shows the isolation between an inverted vee on 40 meters and a vertical with 4 radials about 1 inch above ground modeled with EZNEC. A deep null is achieved when the inverted vee is oriented at 90 degrees or perpendicular to the vertical and so in different polarities while maximum coupling happens when the inverted vee is end-to-end with the vertical. The antenna centers are separated by 300 feet with the inverted vee center at 30 feet above ground and end points 7 feet above ground. Notice that the isolation at its poorest is worse in this case at only about -35 dB than the case of 2 inverted vees where the poorest isolation is about -41 dB.

EZNEC Analysis was also performed on 12 different configurations of 2 antennas for the coupling between the antennas with the antennas separated by 2.5 wavelengths (about 300 feet for 40 meters). A source is setup for a transmit antenna, and the current ratios between transmit and receive antennas indicate the isolation. Some of the results are surprising. Measurements on selected antenna configurations with actual antennas using an open RF range agreed with some error with the EZNEC results. Here are the key results:

1) Vertical to vertical configurations have strong coupling ~ -25 dB **(measured ~ -30 dB)**
2) Parallel dipoles and parallel inverted vees have strong coupling ~ -33.5 dB

3) An inverted vee end-to-end with a vertical has significant coupling (less obvious) ~ -35 dB **(measured ~ -34 dB)**
4) An inverted vee end-to-end with another inverted vee has strong coupling (less obvious) ~ -41 dB
5) Dipoles placed end-to-end reduce coupling but does not provide the best isolation (not obvious that this does NOT provide excellent isolation) ~ -47 dB for 20 feet height - this only varies a few dB versus antenna height and isolation is actually poorer for 40 feet height at ~-44 dB
6) An inverted vee end-to-end with a dipole has reduced coupling but does not provide the best isolation ~ -50 dB
7) A tilted dipole placed end-to-end to another dipole provides excellent isolation – approaches -100 dB – center at 20 feet, close end at 28.7 feet, and far end at 4.1 feet
8) A tilted dipole placed end-to-end to another tilted dipole (tilt in the same direction) provides excellent isolation – approaches -100 dB dB - center at 20 feet, one end at 28 feet and the other end at 12 feet and for a second dipole center at 20 feet, close end at 26.2 feet, and far end at 12.5 feet
9) A tilted dipole placed end-to-end to a vertical provides excellent isolation ~ approaches -100 dB – center at 20 feet, close end at 25.1 feet, and far end at 17.8 feet **(measured ~ -51 dB with no tilt and no tuning and ~ -58 dB with unequal tilt and some tuning)**
10) An inverted vee placed broadside to a vertical provides excellent isolation ~ approaches -100 dB (**measured ~ -54 dB with some tuning**)
11) A dipole placed broadside to a vertical provides excellent isolation approaches -100 dB
12) An inverted vee or dipole placed at 90 degrees to another inverted vee or dipole provides excellent isolation ~ approaches -100 dB

Achieving a large fraction of the high isolations in cases 7 to 12 in practice will almost certainly require end point position tuning in the field for actual antennas. Improving the isolation by more than 10 to 15 dB from the non-tilted dipole situations is likely to not be feasible (or at least very difficult) in practice even though it is possible in simulations. The verticals used 4 radials just above ground level or set to about 1 inch for EZNEC simulations, and insulated wires laid on the ground were used in measurements. The inverted vees used a 90 degree configuration between the 2 legs, and for the field measurements the angle between legs may have been 100 to 120 degrees. The inverted vees used a center support at 30 feet, and the dipoles used a center point of 20 feet.

As expected, configurations 1 and 2 where either vertical or horizontal antennas are broadside to each other provide poor isolation between 2 antennas on the same frequency bands. Configurations 3 and 4 involving inverted vees also provide poor isolation, but this may be less obvious. Configurations 5 and 6 with dipoles end-to-end and a dipole placed end-to-end to an inverted vee provide modest to good isolation, but it is not necessarily obvious why these do not provide excellent isolation. Configuration 5 provides fair isolation, but near field coupling and ground reflections provide significant coupling between the antennas. The reflections invert the signal. So fortunately, the coupled signals can be nulled by providing a directly coupled signal of the about the same strength. This is achieved using antenna tilting with an appropriate amount of tilt to couple directly a signal about equal in strength to the coupled signals. The directly coupled signal is not inverted like the ground reflected signals, so it will null the ground reflections.

The depth of the null is limited by the phase difference deviation from 180 degrees between the direct and reflected signals and possibly reflections from objects in the environment. Since the ground reflected signal travels a slightly longer path than the direct signal this results in a phase deviation between the signals relative to the 180 degrees due to signal inversion at reflection. This means that increasing the height of dipoles reduces the depth of the null that can be achieved by tilting, so it should be understood that the possible null depth depends on: 1) the frequency, 2) the antenna separation; and 3) the antenna height which contribute to the phase shift.   However, if the 2 sides of a dipole are independently tilted, this then allows for the adjustment of the phase and the amplitude of the signals with 2 degrees of freedom and makes it possible to achieve an arbitrarily deep null limited only by non-uniform ground properties, and errors in placement. Since there is control over phase and amplitude in the cancellation signal, even reflections from nearby structures can also be canceled, but any changes in the environment can also limit the depth of nulls.

Configurations 7 through 8 use antenna tilting between end-to-end dipoles and can provide good antenna isolation for Field Day and other situations with interstation interference. The interference is nulled between antennas with compensation for any near field and ground reflections and perhaps reflections from major objects in the environment when tuning is included. In practice, tuning of the end positions of one of the antennas is needed to achieve a deep null since the null depends on ground conditions (terrain, conductivity and dielectric constant) and objects in the environment such as other antennas and buildings.   If only one dipole is tilted, rather strong tilt is needed, but if both dipole are tilted, then less tilt is needed and only one dipole needs unequal tilt.

Coupling between dipoles and verticals was also considered in configuration 9 using tilting for nulling. Placing a dipole or inverted vee with an end facing a vertical is also weak for isolation since the ground reflections between the dipole and vertical couples properly in polarity between the antennas, but if a dipole is tilted appropriately the near field and ground reflections can also be nulled.

With typical ground conditions, EZNEC simulations showed that configuration 9 with a dipole end-to-end to a vertical requires only a small tilt of a 40 meters dipole at 20 feet in height separated by 300 feet from a vertical by raising the end closest to the vertical by about 5 feet and lowering the other end of the dipole by about 2 feet.   Note that the dipole tilt is not symmetric in order to shift the phase to achieve a deep null. For configuration 8 with two tilted dipoles and each at 20 feet in height, the required tilt in the same direction is more significant requiring raising one end on each dipole by 8 feet and lowering the other end by 8 feet, so one end is at 12 feet and the other end is at 28 feet. And for configuration 7 with only one dipole tilted, the tilt is strong requiring the end closest to the other dipole to be at 32 feet and the other end to be at only 8 feet. It may be convenient to construct such antennas using a single tall vertical pole at the higher end of the dipole and sloping the dipole to a ground stake at the other end.

Some of the largest benefits in isolation can be achieved with antennas using different polarities as shown in configurations 10 to 12. Configuration 9 also places the antennas in different polarities, but in this case of a vertical end-to-end to a dipole, the ground reflection couples the signal between horizontal and vertical polarities of the antennas. A dipole or inverted vee placed broadside to a vertical can achieve very good isolation. This is a key point made by Barrett Milliken, KC9CHG and Tim Toman, N9TO. [2 & 3] This may not be so obvious since a dipole or inverted vee has a peak in total radiation broadside to the antenna. But dipoles in different polarities (90 degrees) can achieve very deep isolation in the field, as high as about 60 dB with 300 feet separation on 40 meters. Inverted vees on different polarities also perform well, however with a bit less isolation than dipoles. An inverted vee placed at 90 degrees to a dipole performs about as well as a dipole placed at 90 degrees to another dipole for isolation, and the depth of the isolation is limited by error in the alignment and by non uniformity in the ground and in the environment. Tuning of the end points of the dipole or inverted vee is important for excellent results.

These results use a realistic EZNEC ground model and the model assumes that the ground is flat and homogeneous or consistent everywhere. The principle of reciprocity applies, so isolation is only measured in one direction. Of course a homogeneous ground is probably not so true, especially on a site with uneven terrain. The model also does not consider effects of buildings, trees, and other antennas. Nevertheless, the trends of the results should be correct, especially for a site that is relatively open. Large metal buildings between antennas may render these models poor to useless for isolation, for example. With measurements using actual antennas with an inverted vee broadside to a vertical on 20 meters, we found that a deep null was possible by tuning the end points of the inverted vee which appeared to be compensating for uneven ground, other nearby antennas, and nearby metal buildings.

Testing using actual antennas was performed at the QTH of KA2C for some of these configurations partnering with WA3PTV, Joe Lockbaum. We used 20 meters (scale down by 0.5 from 40 meters) to allow using smaller antennas and a smaller open radio range. Two antennas about 150 feet apart were set up. One was connected to an HW-8 near the radio shack to excite the source antenna (about 25 Vp-p or 1.6 watts into 50 ohms). The other antenna was connected to a scope for monitoring the signal strength at second antenna for isolation. The following results were obtained:

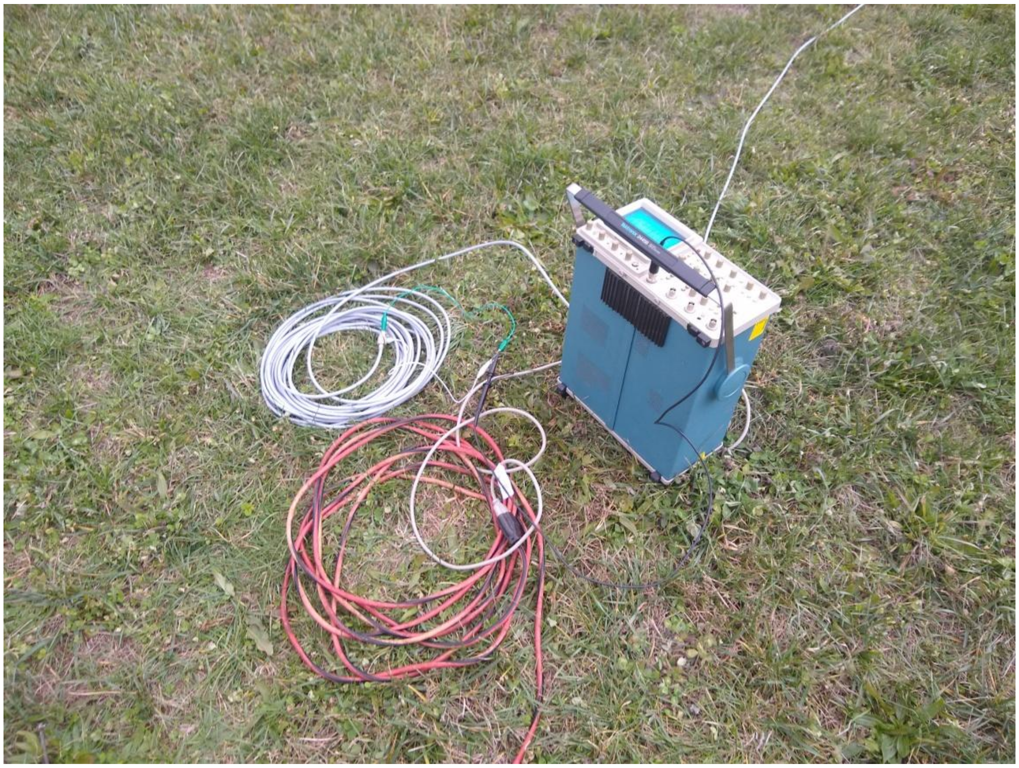
1) Vertical to vertical (received 500 mVp-p or -34 dB) -30 dB removing about 4 dB losses in coax and couplers
2) Vertical to inverted vee end-to-end (received 300 mVp-p or -39 dB) -35 dB removing losses
3) Vertical to inverted vee broadside (received 100 mVp-p or -48 dB) -44 dB removing losses
4) Vertical to inverted vee broadside with some manual tuning of end-points of inverted vee (received 30 mV-p-p after tuning or -58 dB) -54 dB removing losses
5) Vertical to end to end dipole (received 50 mVp-p or --54 dB) -51 dB removing losses
6) Vertical to end to end dipole with some manual tuning and unequal tilt (received 20 mVp-p or -62 dB) -58 dB removing losses

Case 6 achieved about -58 dB in coupling with a 20 meter vertical end to end to a 20 meter dipole only separated by about 150 feet. About 1.5 hours of tuning was required to achieve these results. That much time was needed due to raising and lowering the end points to reposition them for tests. The dipole alignment was moved about 15 degrees from end to end with the vertical antenna, probably due to compensating for reflections from a large metal shed nearby. The final results had the far end of dipole at about 10 feet above ground and the close end at about 12 feet above ground. It was necessary to separately support the center balun to achieve the best result. The final best experimental tilt is in rough agreement with the EZNEC simulations where 7 degrees of tilt was optimal.

Picture 1: The low power test signal was generated on 20 meters using a HW-8

Picture 2: The transmit antenna was a multiband Cushcraft MA-5 operating on 20 meters

Picture 3: The receive or victim antenna in a horizontal position



Picture 4: The signal on the receive or victim antenna was measured with an analog scope across a 50 ohm load

These results suggest that actually tuning dipole or inverted vee end points at a Field Day site is important to achieve excellent isolation performance which is key to operating simultaneously in the same band and may be important for inter-band operation.   W2VJN discusses using your radios themselves to perform this job. You can transmit a QRP signal in the 1 to 5 watt range from a first antenna, measure the received signal level at a receiver connected to the second antenna with the S meter (preamps should be disabled and you should have attenuators of 40 to 80 dB's to insert in the coax to the receiving radio). Insert or remove attenuators to bring the signal level to about the S9+40 dB range. Then tune the dipole or inverted vee end point positions (generally several feet at a time) to minimize the received signal. With antennas separated by only a few hundred feet, it is possible to tune the antenna end points using an oscilloscope as we did in our antenna measurements. Inverted vees are easy to tune if the end points are anchored to ground stakes and allow independently tuning each end point for best null.   A tilted or sloping dipole may also be easier to tune at one end, but fully elevated dipoles would require significantly more effort. It would be possible to use 2 vertical supports combined with pulleys from the top of each support with ropes connected to a movable end of a dipole to provide a fine tuning capability without raising and lowering supports. A third rope staked to the ground would allow raising and lowering the end point. But fair to good results can be obtained without this flexibility.

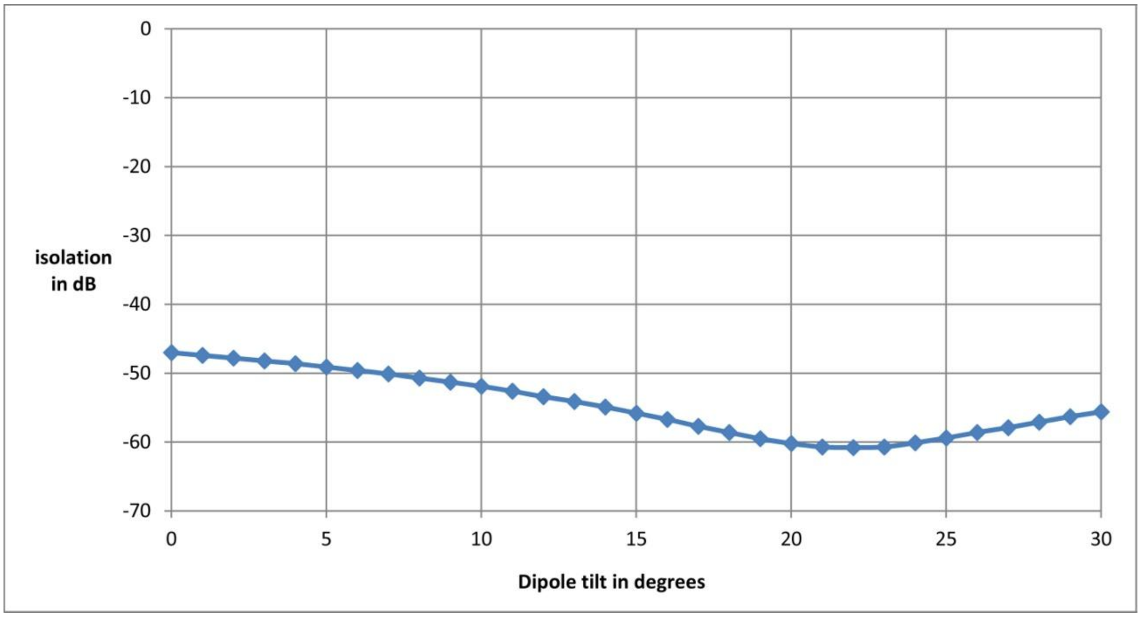


Figure 3: Isolation between end to end dipoles vs tilt angle of one dipole

It was found that tilting of dipoles when they are placed end to end to each other or to a vertical can improve the achieved null significantly by compensating for ground reflections. Figure 3 shows antenna isolation between a fixed dipole on 40 meters at 20 feet in height and a similar dipole spaced 300 feet away (center to center) in an end to end configuration versus tilt of the second dipole in degrees. Minimum coupling is achieved with a significant tilt of about 22 degrees. The isolation is improved by about 15 dB compared to a non-tilted dipole, but the null appears to be limited in depth.

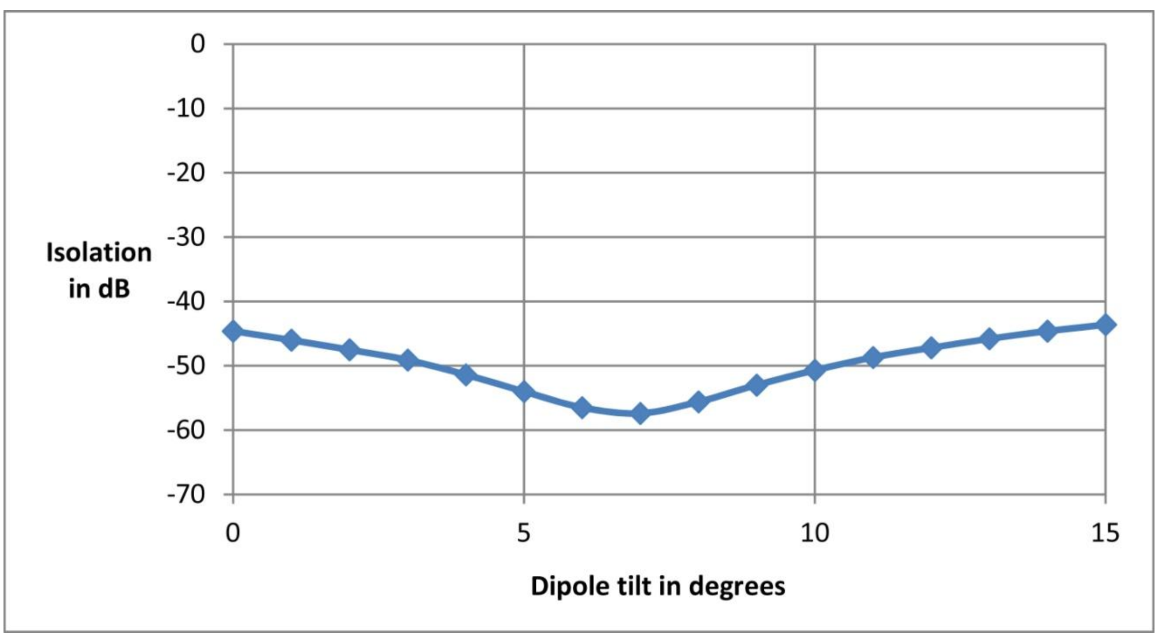


Figure 4: Vertical to end to end dipole isolation versus tilt angle

This Figure shows antenna isolation between a vertical and a dipole on 40 meters at 20 feet in height and a vertical spaced 300 feet away (center to center) in an end to end configuration versus tilt of the dipole in degrees. Minimum coupling is achieved with a modest tilt of about 7 degrees. The isolation is improved by about 12 dB compared to a non-tilted dipole, but the null appears to be limited in depth.

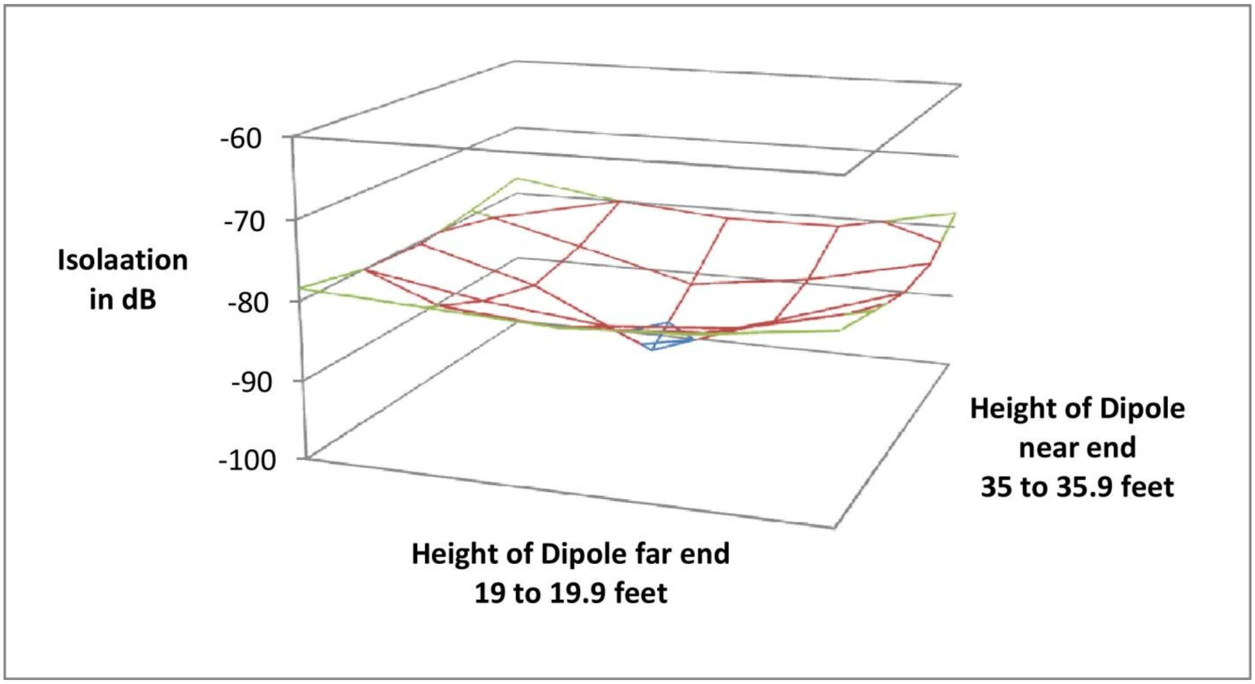


Figure 5: Dipole to end to end unequally tilted dipole for each side with 2-D sweep

Figure 5 shows the isolation for an unequally titled dipole end to end with an equally tilted dipole. The dipoles are at 30 feet in their centers in this case on 40 meters and spaced by 300 feet. The equally tilted dipole has one end raised 9 feet and the other end lowered 9 feet (39 and 21 feet in height). The best result or highest isolation is obtained with the near end of the other or unequally tilted dipole at 35.4 feet and the far end at 19.5 feet. The unequal tilting allows compensation in both amplitude and phase for ground reflections.

Considering a difficult situation with CW, phone, and digital stations all trying to operate on a single band (assume 40 meters) it is possible to obtain excellent isolation with all 3 antennas well within 1000 foot separation as mandated by the Field Day rules (at least ideally but over a realistic ground model). For 3 antennas, you could place them in a 600 foot line with a vertical at one end. Then place an inverted vee next in the line spaced 300 feet and broadside to the vertical or perpendicular to the line to provide polarization isolation with the vertical and the other antenna and tune it for maximum isolation. Using an inverted vee makes tuning of the antenna fairly easy. Then place another dipole 300 feet further down the line parallel with the line and tilted towards the vertical and tune it for maximum isolation with the vertical and with the first dipole. This 3rd antenna has polarization isolation with both the vertical and the first dipole and tilting is used to compensate for ground reflections coupling into the vertical.

An additional EZNEC simulation of this 3 antenna configuration shows that coupling with these arrangements can approach -100 dB ideally for all cases including modeling with a realistic ground model and thus including ground reflections (in practice achievable isolation is likely to be considerably less). The tilted dipole has a height of 34.7 feet on the end towards the vertical and 25.8 feet on the far end with the center at 30 feet. Using a single 35 foot support at the near end, the antenna can be tuned by adding a thin rope of about 175 feet in length to the top of a 3 to 4 foot stake. By moving the stake and by adjusting the tightness of the rope, the antenna can be tuned for isolation. Notice that the non-symmetry of the tilt is small, but in this case it corresponds to a small droop at the center point. The fairly long distance between the vertical and the tilted dipole results in very small phase shift in the ground reflected signal relative to 180 degrees. Of course tuning for good nulls in the field would be important.

Conclusions:

Ground reflections and other factors in real Field Day environments significantly impact the isolation that can be practically achieved between antennas. However, the use of differently polarized antennas is powerful to isolate antennas, and using a dipole or inverted vee broadside to a vertical is very effective. Dipole tilting provides a simple technique to significantly enhance antenna isolation when dipoles must be placed end-to-end to other dipoles or to a vertical and is especially important to provide excellent isolation when 3 antennas are considered. A slight tilt of an end-to-end dipole towards a vertical can null the coupled signals, while a larger tilt may be required between end-to-end dipoles to achieve excellent isolation. Achieving best performance requires unequal tilt of the 2 sides of a dipole to adjust both phase and amplitude of nulling signals, but unequal tilt may be difficult to implement and tune in practice while equal tilting may be more practical. Using an antenna simulation program to analyze a setup and to optimize isolation is recommended. For any of these techniques, actual tuning of the end points of the antennas in the operating environment is important for excellent isolation and due to real environment issues the tuned antenna may deviate noticeably from simulation results.

References:

1) Managing Interstation Interference, W2VJN, George Cutsogeorge
2) Mitigating Field Day Multistation Interference -- Part 1, Milliken, Barrett, KC9CHG and Toman, Tim, N9TO, Sep 2010 – National Contest Journal (Pg. 17)
3) Mitigating Field Day Multistation Interference -- Part 2, Milliken, Barrett, KC9CHG and Toman, Tim, N9TO, Nov 2010 – National Contest Journal (Pg. 13)
4) https://www.kkn.net/dayton2009/W3AO_2009.pdf
5) https://www.kkn.net/dayton2009/Dayton_FD_W2RDX.pdf
6) https://www.onallbands.com/setting-up-multiple-antennas-4-tips-on-avoiding-interference/
7) https://www.arrl.org/files/file/Technology/tis/info/pdf/8809017.pdf
8) http://www.w0qe.com/Technical_Topics/phase_noise_and_overload_testing.html
9) https://forums.qrz.com/index.php?threads/interference-on-field-day.568087/
10) https://www.n1nc.org/Filters/
11) https://www.contesting.com/forums/tips/148